THE TREATMENT OF FRACTURES

By LORENZ BOHLER, M. D
Director of the Accident Hospital, Vienna XX,
Professor of Accident Surgery, University of Vienna

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Translated from the Thirteenth German Edition by
Otto Russe, M D , Director of the Accident Hospital, Vienna XII
and
R G B Bjornson, M D , Diplomate, American Board of Radiology

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CONTENTS

49. INJURIES OF THE HIP

The following injuries may occur in the hip region

1 Fracture of the acetabulum without displacement,
2 Fracture of the acetabulum with central dislocation of the femoral head,
3 Posterior dislocation or fracture-dislocation of the hip,
4 Anterior dislocation or fracture-dislocation of the hip,
5 Separation of the proximal femoral epiphysis (head),
6 Fracture of the femoral neck,
7 Fracture in the trochanteric region;
8 Sprain of the hip joint,
9 Contusion of the hip region,
10 Wounds of various areas and depths

Examination in Recent Injuries of the Hip. The basic essentials for adequate treatment are the earliest and most accurate possible recognition of the local morbid process together with particular awareness of the patient's general condition Therefore, all patients must first be examined clinically and then, if possible, roentgenologically.

Previous History The patient's name, age, profession, address, body height and weight are recorded The mode of injury is determined and is usually found to have been a fall, or an accident in which something has fallen upon or caved in upon the patient (or one in which he has been run over) He then had pain, was unable to walk, and the involved limb fell into external rotation or was flexed at the hip with either adduction and internal rotation or abduction and external rotation

Inspection One determines whether the patient is pale or is in shock and whether he complains of pain Without removing the patient's clothing or shoes one notes whether hip and knee joints are extended or flexed and whether and to what extent the limb is rotated internally or externally.

Flexion of hip and knee with internal rotation and adduction of the thigh suggests a posterior dislocation of the hip, flexion of hip and knee with external rotation and abduction of the thigh suggests an anteroinferior dislocation of the hip External rotation of the thigh of 50° to 60° with flexed hip and knee suggests a central dislocation of the hip, 50° to 60° external rotation with extended hip and knee suggests an intracapsular fracture of the femoral neck A 90° external rotation of the limb with the knee and hip extended indicates an anterolateral dislocation of the hip or a fracture through the trochanteric region The limb is lengthened only in the anteroinferior dislocation of the hip, the limb is shortened in all the other types of injuries

After these observations have been made, the patient is stripped of his clothes and shoes in a warm room so that both lower limbs and the pelvis can be examined *During this the patient must be protected from chilling* After having recorded the patient's general condition, one determines the position of the limb relative to the pelvis (extension or flexion, adduction or abduction, external or internal rotation, shortening or lengthening) One determines whether the pelvis lies straight or oblique, whether the hip region is

swollen, broadened or sunken, whether there is any unusual prominence anteriorly or posteriorly and whether excoriation or discoloration of the skin or a hematoma is present Then one examines the color of the limb and the condition of the muscles

Then the dorsalis pedis and posterior tibial pulses are taken bilaterally, after which the patellar tendon reflex on the sound side is tested The form and diameter of the pupils are noted and their reactions to light and accommodation are tested

The patient is told to move the toes, the subtalar and ankle joints, the knee and the hip joints of the sound side through their full range of motion Then he is told to move the joints on the injured side as much as possible, and then for comparison to move both sides at once He should then try to raise the extended limb and to flex and extend the knee

Palpation Only after having recorded all results of the inspection should one touch the patient By striking rather gently against the heel one examines for impingement pain, and by slight torsion one attempts to elicit rotation pain Then one palpates the trochanteric and the femoral neck regions In the case of fracture there will be pain on pressure, in the case of dislocation one may be able to palpate the empty acetabulum and the femoral head anterior or posterior to it For a short while after the accident one can usually even see the prominence caused by the dislocated femoral head Passive motion is next tested In dislocations the joint shows a "springy fixation" in an abnormal position In fractures some range of painful passive movement is found Lastly, the length of each lower limb is measured from the anterosuperior iliac spine to the tip of the medial malleolus with both hips and knees in the same degrees of abduction and flexion The patient is then covered with a blanket and warmed with a "baker" if necessary

X-ray Examination Only after we have made as exact a diagnosis as possible on the basis of the thorough clinical examination do we have anteroposterior and lateral roentgenograms made to allow us to confirm the diagnosis and to recognize details such as fracture-dislocation With dislocations it is best to make also an anteroposterior scout roentgenogram of the whole pelvis including the hip joints and the proximal parts of both femora.

50. DISLOCATION OF THE HIP

GENERAL

Etiology of Dislocation of the Hip

It results from (1) leverage and rotation; (2) thrust; (3) thrust and leverage; or (4) leverage or thrust with continuing force.

Because of the depth of the acetabulum and the strength of the ligaments and muscles supporting the hip, dislocation of the hip is comparatively rare but is more common than dislocation of the knee.

1 Dislocation of the Hip Caused by Leverage and Rotation It results from the action of considerable force on the femoral shaft, as for example when one is buried by collapsing walls or is injured in a fall from great height or a

fall when moving at high speed, as in a motorcycle or skiing accident, or when one is run over. In only one of our 79 cases did dislocation result from mere slipping on the street Posterior dislocation results from abnormal adduction, flexion and internal rotation Anterior dislocation results from abnormal abduction and external rotation. The shaft and the neck of the femur then lever the femoral head over the fulcrum of the acetabular margin Sometimes the thigh moves away from the more-or-less fixed pelvis; often the pelvis moves away from the more-or-less fixed thigh This leads to simple dislocation of the hip (figs 1528 and 1529/I a—d, 1530/I a—d, 1531 and 1532) or dislocation with avulsion fracture of ligamentous insertions (fig 1530/II)

2 *Fracture-Dislocation of the Hip Caused by Thrust.* It most frequently results from automobile collision when the car is abruptly stopped. Knees and legs then hit against the dashboard or front seats and are stopped there, whereas the pelvis and the other parts of the body tend to keep moving The dorsal or superoposterior wall of the acetabulum is thus thrust forwards against the fixed femoral head and is sheared off by it (figs. 1530/III—IV, 1532 c—g, 1546 b—c, 1547—1556) If the hip joint is flexed to a right or acute angle the dorsal edge of the acetabulum is sheared off With adduction of the thigh (as, for example, with crossed legs) the fragment will be smaller, with abduction of the thigh the fragment will be larger (figs 1530/III and 1546 a) If the trunk is inclined backwards at the moment of collision and the hip joint is therefore in semiextension, a big dorsosuperior bone wedge is sheared off (figs 1530/IV and 1546 b) In this type of accident (dashboard dislocation), injuries to the front of the knee are often associated, ranging from simple contusion and laceration up to compound fracture of the patella, of the tibial head and/or of the distal end of the femur.

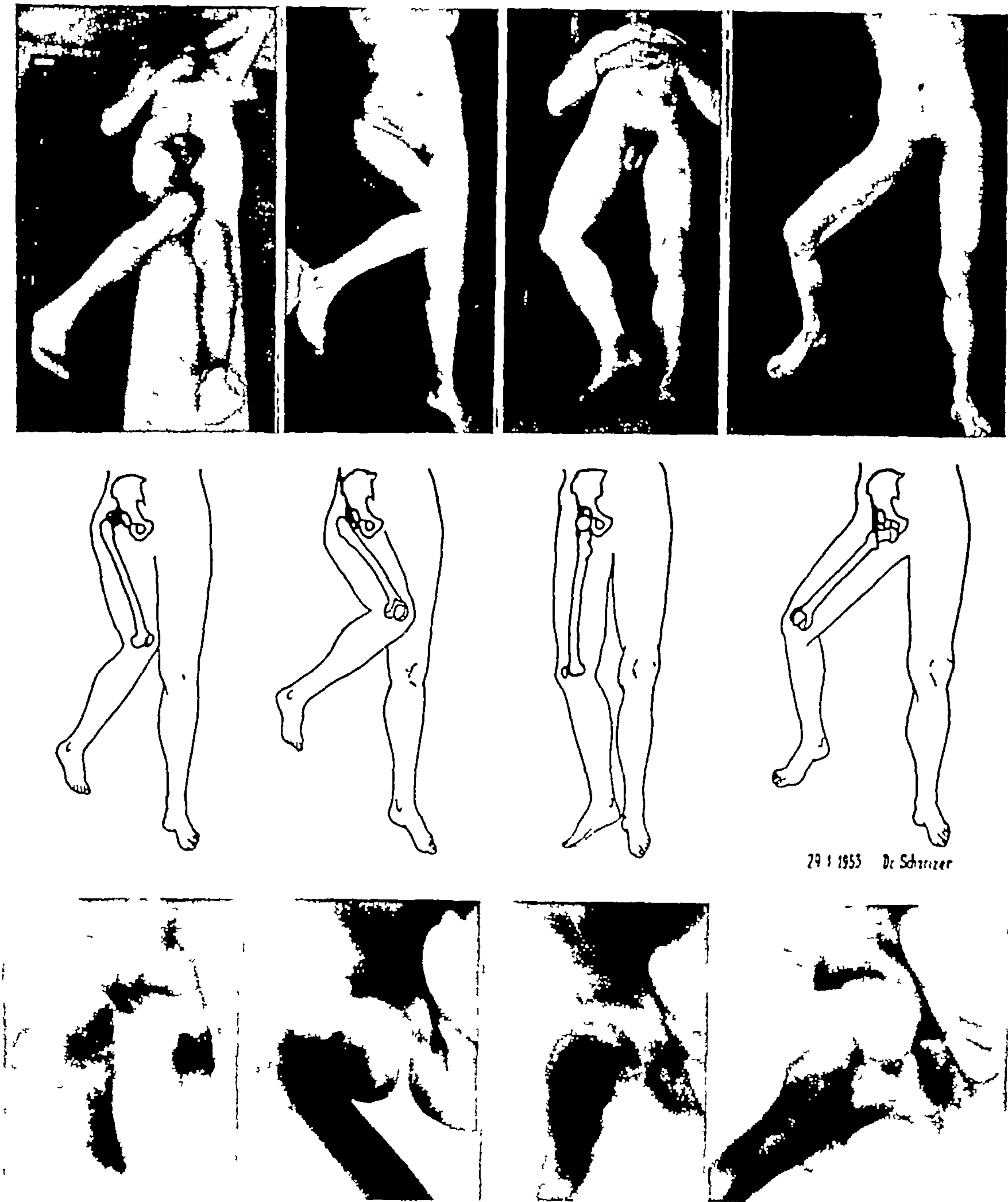
3 *Fracture-dislocation Caused by Thrust and Leverage* This occurs when a thrust applied against the greater trochanter in the long axis of the femoral neck fractures the acetabulum Then the femoral head is levered out of the acetabulum (fig 1530/V)

A marginal fragment of the femoral head is sheared off (fig 1530/VI) if a thrust is applied in the long axis of the femoral shaft prior to the dislocation of the femoral head

4 *Fracture-dislocation of the Hip Caused by Leverage or Thrust with Persistence of the Force Which Has Led to Dislocation* If after dislocation of the hip the acting force continues, it may lead to separation of the upper femoral epiphysis (fig 1530/VII), to fracture of the femoral neck (fig 1530/VIII and fig 1557) or to fracture of the femoral shaft (fig 1530/IX)

Classification of the Dislocations of the Hip According to the Position of the Femoral Head

According to the position of the femoral head in relation to the pelvis we differentiate between anterior and posterior, and within these two groups we again differentiate between superior and inferior, dislocations There are also dislocations in which the femoral head lies exactly anterior or posterior to the acetabulum They can easily be missed in a frontal roentgenogram (figs 1532 a, 1538, 1542, 1547) Posterior dislocations occur five times as



1528/I a 1528/I b 1528/I c 1528/I d, July 15, 1952

FIG. 1528/I a—Luxatio iliaca The dislocated limb is internally rotated, slightly flexed at the hip and adducted so far that the knee of the injured side lies close to the other knee In the roentgenogram and the skeletal drawing the femoral head is seen to be dorsal, superior and lateral to the acetabulum The lesser trochanter is not seen—a sign of internal rotation

often as do anterior ones Posterior dislocations there are more often superior, while anterior dislocations are more often inferior

Among the *posterior dislocations of the hip*, the superior is called luxatio iliaca (figs 1528/I a, 1529/I a and 1531) and the inferior is called luxatio ischiadica (figs 1528/Ib, 1529/I b and 1532)



1529/I a 1529/I b 1529/I c 1529/I d, August 1, 1952

FIG 1528/I b—Luxatio ischiadica The dislocated limb is in a position of extreme internal rotation, flexion and adduction The knee of the injured side lies on the sound thigh Radiologically and diagrammatically the femoral head is shown to be dorsal, inferior and lateral to the acetabulum The lesser trochanter is not seen because of the marked internal rotation, and the findings simulate those of a coxa vara

FIG 1528/I c—So-called luxatio pubica or ileopectinea 90° external rotation, extension and approximately 15° abduction of the limb The femoral head can be seen and palpated as a ball-like swelling in the inguinal region Radiologically and diagrammatically the femoral head is shown to be caudal, lateral and anterior to the acetabulum The entire lesser trochanter is seen in profile, the greater trochanter lies behind the femoral head in the acetabulum

FIG 1528/I d—Luxatio obturatoria Approximately 40° external rotation, 40° flexion and 50° abduction of the dislocated limb Radiologically and diagrammatically the femoral head is shown to be in front of, below and medial to the acetabulum and in front of the obturator foramen The entire lesser trochanter is seen in profile

FIG 1529/I a—d—Luxatio iliaca, ischiadica, pubica or ileopectinea and obturatoria Top row shows anterior view, middle row shows lateral view, bottom row shows posterior view

Among the *anterior dislocations of the hip*, the superolateral is called luxatio pubica or iliopectinea (fig 1528/I c) and the inferomedial one is called luxatio obturatoria (fig. 1528/I d).

The clinical features of the four different types of dislocations can be studied in figures 1528 and 1529 a—d

Concomitant dislocations of both hips may also occur They may be of the same or of different types We have seen one bilateral case.

Pathologic Anatomy of Dislocation of the Hip Joint

Injuries to the Capsule and the Ligaments The femoral head can leave the acetabulum only if the ligamentum teres has been torn or avulsed from the femoral head In autopsies I have seen it torn off at its proximal or distal extremity The head dislocates either anteriorly medial to the iliofemoral ligament or posteriorly where strong ligaments are lacking and where the acetabular lip is somewhat low. Posterior dislocations occur through the greater sciatic notch, anterior ones through the acetabular notch There the capsule tears The iliofemoral ligament is generally preserved If it is torn there is no "springy fixation" of the joint The result is a strikingly high or strikingly lateral position of the femoral head

Injuries to the Muscles In posterior dislocations the short rotators, especially the quadratus femoris and the gemelli, are more or less torn The glutaei are only bulged out

In anterior dislocations, extensive tears of the adductors are the rule. In one of our cases, described by Wittmoser,[1] the pectineus and the adductors minimus and brevis had been torn completely through and the ileopsoas had been torn two-thirds through The medial femoral circumflex artery had been torn and thrombosed The posterior short rotators, specifically the piriformis, the obturator internus and the gemelli, had not been injured.

Injuries to the Acetabulum In dislocations of group II, localized avulsions of ligamentous attachments occur at the superior or inferior lip of the acetabulum (fig 1530/II) After reduction the joint is invariably stable

In dislocations of group III, minor and sometimes major parts of the posterior lip of the acetabulum are sheared off (fig 1530/III) The joint will generally be stable after reduction Prognosis is good we have never seen any avascular necrosis among our cases.

In dislocations of group IV, one or more big bone wedges are sheared off from the posterior part of the acetabular roof (fig 1530/IV). The joint will invariably be unstable Prognosis is grave avascular necrosis has occurred in every second case we have seen and arthrotic changes have developed in all the rest

In dislocations of group V, the floor of the acetabulum is broken (fig. 1530/V) and the fragments are generally displaced The joint will be unstable after reduction Fractures of the acetabulum of groups II—V (figs 1530/II—V) occur in superoposterior dislocations

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[1] Wittmoser, R "Eine ungewohnliche Huftgelenksverrenkung" Beitr klin Chir *176* 583 603, 1947

Injuries to the Femoral Head and Neck. In some of the fracture-dislocations of groups III (fig 1530/III) and V (fig 1530/V) and more often in those of group IV (fig 1530/IV), the cartilaginous coat of the femoral head will show fissures and detached fragments They are, of course, not visible in the roentgenograms Arthrotic changes may result later on

In fracture-dislocations of group IV (fig. 1530/IV), a large upper posterior bone wedge is sheared off from the acetabular roof The upper part of the femoral head is probably compressed and crushed during the accident After the violent force has ceased, the head regains its former shape (Jorg Bohler [1]) Changes in the structure of the trabeculae are not recognizable in our present-day roentgenograms

Sometimes not only a part of the articular cartilage but also a large marginal fragment of the femoral head is sheared off (fig 1530/IV). Dislocations of this kind are generally stable after reduction

In children up to the age of 16, an upper femoral epiphysis loosened during dislocation may become displaced if the violent force continues after dislocation (fig 1530/VII) Fracture-dislocations of this kind cannot be reduced without open operation

In adults, continuance of the force after dislocation may cause a fracture of the femoral neck (fig 1530/VIII) or of the femoral shaft (fig 1530/IX) Fracture-dislocations of this kind, too, must be treated by open operation

Marginal fragments of the femoral head (group VI, fig 1530/VI) are sheared off in superoposterior and inferoanterior dislocations

Our experience with displacements of the upper femoral epiphysis (group VII, fig 1530/VII) has been limited to old dislocations of the superoposterior type

We have seen fractures of the femoral neck (group VIII, fig 1530/VIII) in superoposterior and anterolateral dislocations

We have seen fractures of the femoral shaft (group IX, fig 1530/IX) in posterior and anterior dislocations

Injuries to the nerves with paralysis of the sciatic nerve or of the peroneal nerve occur mostly in those posterior fracture-dislocations in which reduction has been delayed Femoral nerve lesions occur in anterolateral dislocations only [2]

Injuries to the Vessels Ruptures of the femoral artery occur in open dislocations of the anterolateral type In closed anterolateral dislocations the femoral head may press on the artery and displace it laterally

Classification of Dislocations of the Hip according to the Concomitant Injuries to the Hip Joint and to the Prognosis in those Injuries

The general classification of anterior and posterior, superior and inferior dislocations of the hip concerns diagnosis only It indicates nothing about prognosis, which depends upon·

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[1] Bohler, Jorg Experimentelle Untersuchungen uber die Kompression von Schenkelkopfen Der Chirurg *24* 344, 1953

[2] Trojan, E Ischiadicus- und Peronaeuslahmungen nach traumatischen Huftverrenkungen und Huftverrenkungsbruchen Schweiz med Wchnschr *83* 734, 1953

(1) the mechanism of injury and the resulting concomitant injuries in the region of the acetabulum and the thigh, and

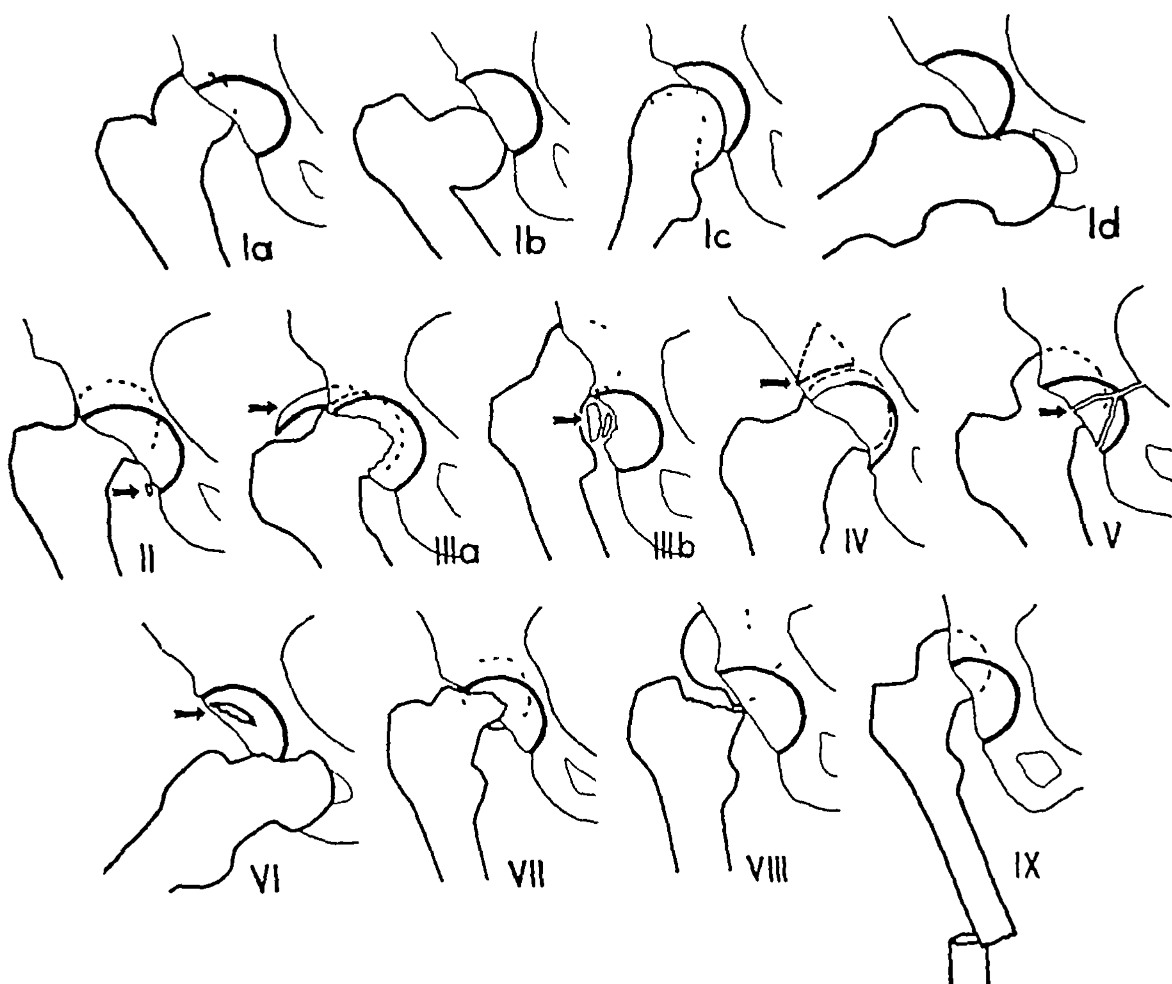
(2) the nature of the treatment

As in dislocations of the elbow (see Vol I/p 694), there are two main groups of dislocations of the hip, viz, pure dislocations of the hip (DH) and fracture-dislocations of the hip (F-DH) with major or minor marginal fractures of the acetabulum, of the femoral head, or of the femoral neck

In dislocations caused by leverage, prognosis is much better than in those caused by thrust, the latter involving sometimes grave injuries to the acetabulum or the femoral head Prognosis depends also on the treatment The earlier the dislocation is recognized and carefully reduced, and the simpler the postreduction treatment is, the better the prognosis. Special care should be taken to protect the joint from the irritation of postreduction massage and passive motion Prognosis is grave in dislocations with a fracture of a marginal fragment of the femoral head or in dislocations with a simultaneous fracture of the femoral neck

We have classified our 79 recent cases according to the following scheme:

A	*Pure Dislocations of the Hip (DH)*	43 cases	(54.43%)
	Group I Pure Dislocations without injury to the bones, subdivided as follows:		
	a) Pure superoposterior DH Luxatio coxae iliaca	24 cases	(30.38%)
	b) Pure inferoposterior DH Luxatio coxae ischiadica	9 cases	(11.39%)
	c) Pure anterolateral DH Luxatio coxae pubica or iliopectinea	1 case	(1.27%)
	d) Pure antero-inferomedial DH Luxatio coxae obturatoria	9 cases	(11.39%)
B	*Dislocations of the Hip with Fracture of the Acetabular Region Without Central Dislocation (F-DH)*	28 cases	(35.44%)
	Group II Superoposterior fracture-dislocation (F-DH) with chip fractures of capsular insertion	7 cases	(8.86%)
	Group III Superoposterior F-DH with shearing off of the lip of the acetabulum	10 cases	(12.65%)
	Group IV Superoposterior F-DH with fracture of one or more bone wedges at the superoposterior part of the acetabulum (roof of the acetabulum)	8 cases	(10.13%)
	Group V. Posterior F-DH with fracture of the acetabular floor with or without displacement	3 cases	(3.80%)
C	*Dislocations of the Hip with Fractures of the Femur (F-HD)*	8 cases	(10.13%)
	Group VI Dislocation of the hip with a marginal fragment from the femoral head	3 cases	(3.80%)



1530, Group I–IX, sketched in July 1952

FIG 1530/I a —Pure luxatio iliaca with slight adduction, flexion and internal rotation (Group I a)

FIG 1530/I b—Pure luxatio ischiadica with severe adduction, flexion and internal rotation (Group I b)

FIG 1530/I c—Pure luxatio pubica or ileopectinea, with slight abduction and maximum external rotation (Group I c)

FIG 1530/I d—Pure luxatio obturatoria with severe abduction and moderate flexion and external rotation (Group I d)

FIG 1530/II—Luxatio iliaca with avulsion fracture of ligamentous insertion (Group II)

FIG 1530/III a—Luxatio iliaca The posterior lip of the acetabulum is sheared off and displaced cranially and posteriorly (Group III)

FIG 1530/III b—Luxatio iliaca eversa with detachment of two pieces of bone from the posterior lip of the acetabulum which remain caudal to the femoral head (Group III) The femoral head is in a strikingly high position and the limb is externally rotated as shown by the lesser trochanter which appears bigger than usual

FIG 1530/IV—Luxatio iliaca with detachment of a large posterosuperior bone wedge from the acetabular roof (Group IV)

FIG 1530/V—Luxatio iliaca with fracture of the floor of acetabulum (Group V)

FIG 1530/VI—Luxatio obturatoria with marginal fragments from the head of the femur (Group VI)

FIG 1530/VII—Luxatio iliaca with complete displacement of the femoral head epiphysis (Group VII)

FIG 1530/VIII—Luxatio iliaca with fracture of the femoral neck (Group VIII)

FIG 1530/IX—Luxatio iliaca with simultaneous ipsilateral fracture of the femoral shaft (Group IX)

Group VII	Dislocation of the hip with epiphyseal displacement of the femoral head	0 cases (0%)
Group VIII	Dislocation of the hip with fracture of the femoral neck	4 cases (5.06%)
Group IX	Dislocation of the hip with fracture of the ipsilateral femoral shaft	1 case (1 27%)

Of Group VII we have seen only two cases, both old

Open dislocations of the hip have been observed twice in our 79 cases, viz , an anterolateral one and an anteroinferior one Both patients died within a few hours

Concomitant injuries to areas other than the hip are seen in almost every second case. Apart from open and closed fractures of the lower leg, fractures of the vertebrae with or without paralysis, serial fractures of the ribs and various other injuries may occur

Congenital and pathologic dislocations of the hip are not included here

Classification According to Age and Sex

Most of our 79 cases occurred in patients between the ages of twenty and sixty Our youngest patient was six years of age, our oldest 75 About 90 per cent of our patients were well-developed men, only about 10 per cent were women In elderly people with osteoporosis, forces of a kind which in younger people would cause dislocation of the hip generally cause fractures of the femoral neck or of the trochanteric region instead.

Complications Following Dislocation of the Hip

They may occur immediately or they may occur months or even years later We therefore distinguish between early and late complications

Early Complications

1 Death,
2 Amputation or enucleation,
3 Impeded blood-supply, and
4 Nerve lesions.

Late Complications

1 Myositis ossificans,
2. Avascular necrosis of the femoral head,
3 Arthrotic changes, and
4 Pain and limited motion

Causes, prevention and treatment of early and late complications will be discussed on pages 1116 and 1119

CLINICAL EXAMINATION IN SUSPECTED DISLOCATION OF THE HIP

When the pain-racked patient is admitted to the hospital or is found at the site of the accident, one usually recognizes even in the fully-clad patient one of the deformities shown and described in figures 1528 and 1529 a—d Shock, which is often present, is indicated by pale face and lips, cold sweat on the forehead and rapid, thready pulse. The previous history generally suggests a grave accident

When the patient is stripped, deformities as shown in figures 1528 and 1529 a—d can be better observed The color of the limb is usually normal Upon trying to move the injured limb in the hip joint one notices a "springy fixation" of the limb in its abnormal position Crepitation suggests

simultaneous fracture of the acetabulum or of the femoral head Sometimes the dislocated femoral head can be seen or palpated

General Examination Careful local examination must not be thought to make a careful general examination unnecessary The general examination is carried out as described in Vol I/pp 8—14 After having recognized the patient's pale, sweat-covered face as a sign of shock, one checks the radial pulse If it is rapid and thready, the blood pressure should be taken The dorsalis pedis and posterior tibial pulses must also be checked

Then the patellar tendon reflex on the sound side is tested, and the pupils are examined relative to their diameter, their form and their reactions to light and accommodation

Then the active motion of all lower limb joints is tested, first on the sound side and then on the injured side, starting from the toes and progressing upward to the hips If the toes and the foot on the injured side cannot be moved because of involvement of the sciatic or the peroneal nerve, sensibility should also be tested

Since every second dislocation of the hip is accompanied by injuries to other parts of the body, the patient should always be checked as to pain, deformities and discolorations All joints of both arms should be examined, starting from the fingers and progressing up to the shoulders, in order that no injury be overlooked Moreover, and especially in unconscious patients, the head and trunk should be carefully and thoroughly examined for wounds, discolorations and deformities

X-Ray Examination. With a certain amount of experience, one can recognize most dislocations of the hip at first sight As a rule, however, simultaneous injuries to the acetabulum and the femoral head as well as their character and extent cannot be determined clinically Therefore an anteroposterior *roentgenogram of the whole pelvis* should be made in every case of dislocation of the hip (after one has treated the patient for pain and shock by local anesthesia and warming) in order to allow comparison with the sound side as well as to allow recognition of eventual abnormalities on the supposedly sound side This will be important for subsequent disability assessments and follow-up examinations The pelvis should be positioned at exactly right angles (not obliquely) to the longer axis of the X-ray table (figs 1531, 1532 b) It will then be easy to notice that the femoral head of the injured side is in a position more cranial or more caudal than that of the femoral head on the sound side This is especially important with posterior fracture-dislocations of Group IV (fig 1532 c) in which the dislocation may be otherwise overlooked and the injury considered to be just a fracture of the acetabular roof (fig 1531—1532 b)

If in the roentgenogram the femoral head shadow coincides with that of the acetabulum as in figures 1528 c, 1532 a, 1538, and 1542, because it is in a position exactly anterior or posterior to it, the dislocation is often overlooked, although the clinical examination had shown every sign of a dislocation of the hip To avoid this, lateral or oblique roentgenograms should also be taken Special attention should be paid to outlines and position of the femur in the anteroposterior roentgenograms

For *lateral roentgenograms* the patient can be placed on his injured side (fig 1532 c), although good pictures will be rare in this case It is better if the lateral roentgenograms are made as in the operation for fractures of the femoral neck (figs. 1702, 1703) Lateral views of posterolateral dislocations are especially impressive, the femoral head being in an extremely anterior position as in the lateral skeletal drawing shown in figure 1529 c.

Roentgenograms made in the oblique projection(s) are better. The patient is placed on his sound side so that the coronal plane of his back forms an angle of about 45° with the surface of the X-ray table. The roentgenogram is then made in this position The femoral head will be found to have left the acetabulum posteriorly (fig. 1532 g) These oblique pictures are especially valuable with fracture-dislocations in which there is a posterosuperior wedge fractured from the acetabular roof Such fractures are frequently overlooked in anteroposterior roentgenograms, since the position of the femoral head in



December 19, 1932

Fig 1531—Postero-superolateral dislocation (luxatio iliaca) of the right hip occurred in a 20 year old female student in a skiing accident The acetabulum is empty, the femoral head is displaced superiorly, laterally and posteriorly, the femoral shaft is adducted and internally rotated, so the lesser trochanter is not seen Reduction after 24 hours The femoral head "jumped" back into the acetabulum after traction for 15 minutes Normal walking after one week No complaints at the follow-up examination nine years later (case 6 of Obwegeser, case 3 of Trojan)

relation to the large fragment of the acetabular roof displaced posteriorly and superiorly is normal This bone wedge sheared off posteriorly is closer to the X-ray film than is the undisplaced anterior part of the acetabular roof and will therefore appear more distinctly in the roentgenogram Moreover, the anterior undisplaced part of the acetabular roof is caudal to the cranial surface of the femoral head and therefore appears less distinctly (fig 1532 c) These things taken together explain why this type of fracture-dislocation is overlooked so frequently and considered to be just a fracture of the acetabular roof. It should be noted that isolated fractures of the acetabular roof do not occur without simultaneous posterior dislocations of the hip.

In case of doubt, *stereoscopic roentgenograms* can be taken. If there is no X-ray apparatus available, reduction of the clinically determined dislocation

should not be delayed after any eventual shock has been treated Roentgenograms, however, should then be made as soon as possible after reduction

Diagnosis of Dislocation of the Hip. With pure dislocation of the hip, diagnosis is comparatively simple If, following abrupt and forceful trauma, the limb cannot be used, if there is great pain in the hip region, and if the hip shows "springy fixation" in one of the pathologic positions shown and described in figures 1528 and 1529 a—d, there is great probability of a dislocation of the hip Adduction, inward rotation and flexion suggest a posterior dislocation (figs 1528 a, b), abduction, outward rotation and flexion suggest



June 1, 1935

FIG 1532—Antero-inferomedial dislocation (luxatio obturatoria) of the left hip in a 27 year old man who jumped from a truck and was run over The acetabulum is empty, the femoral head is displaced inferiorly, medially and anteriorly, the femoral shaft is strongly abducted and externally rotated so that the greater trochanter disappears behind the femoral shaft The lesser trochanter, visible in full profile in the anteroposterior view with this dislocation, is unfortunately cut off in part in this picture In addition, there is dislocation of the left innominate bone at the pubic symphysis and the sacroiliac joint Patient died after one hour and a half because of concomitant lacerations of the lung, spleen and kidney (case 10 of Obwegeser and 39 [5] of Trojan)

an anteroinferior one (fig 1528 d) It is easy to recognize the anterolateral dislocation by the position of the femoral head, which is clearly visible and palpable in the inguinal region, and by the marked external rotation (fig 1528 c) With this rare dislocation the limb will sometimes be pale or will show bluish spots, since the femoral artery is displaced laterally and more or less throttled by the femoral head The dorsalis pedis and posterior



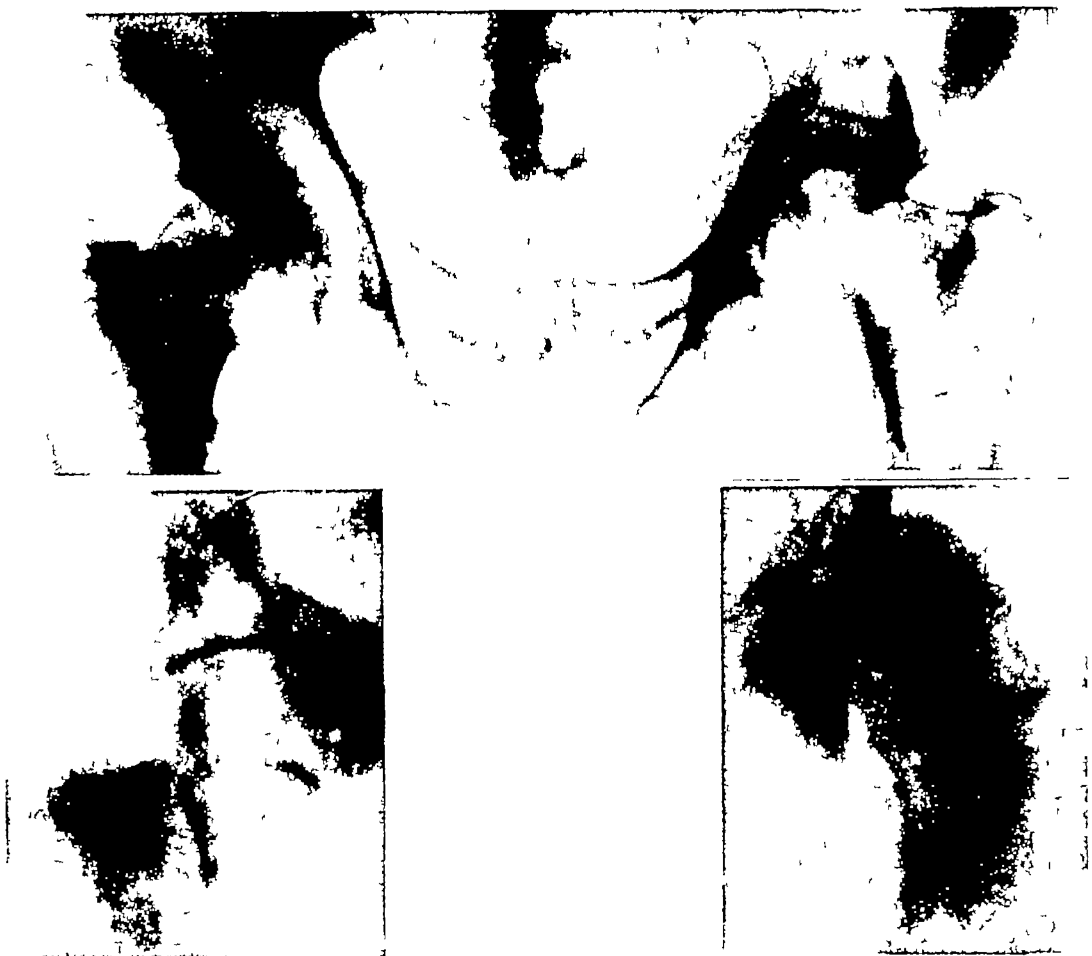
1532 a–d

Fig. 1532 a, top—Posterior dislocation of the right hip (luxatio iliaca), which may be easily overlooked, since the femoral head is directly posterior to the acetabulum and its shadow is deceptively superimposed on the shadow of acetabulum The only suggestion here of dislocation is in the femoral shaft's being adducted and in the lesser trochanter's being invisible in profile because of the internal rotation of the femur The greater trochanter largely disappears on each side because both hips are somewhat flexed Clinically the patient showed springy fixation of the hip-joint with internal rotation, flexion and adduction of the right lower limb shortly after a severe accident

Fig. 1532 b, middle—Comparison picture re figure 1532 a, after reduction Adduction of the involved femoral shaft has disappeared The lesser trochanter is of the same size as on the sound left side The greater trochanter is plainly visible on both sides because the hips are no longer flexed

Fig. 1532 c, bottom left—Lateral roentgenogram of the pelvis before reduction Because of a slight posterior rotation of the right side the left acetabulum is seen anterior to the right one The left femoral head lies in the acetabulum, whereas the right one can be seen posterior to the empty right acetabulum

Fig. 1532 d, bottom right - Comparison picture re figure 1532 c, after reduction Now the right femoral head also lies in the acetabulum



1532 e, f, g, October 15, 1952

FIG 1532 e—Anteroposterior roentgenogram of the whole pelvis in a five month old luxatio iliaca of the left hip with avulsion of a posterosuperior wedge from the posterior part of the acetabular roof The dislocation was overlooked for five months despite repeated roentgenograms made in different hospitals and was considered to be an isolated fracture of the acetabular roof The patient showed clinically, however, a marked internal rotation and flexion of the limb Looking carefully, one notices that the femoral head is diplaced superiorly with the posterosuperior part of the acetabular roof The anterior undisplaced part of the acetabular roof is not clearly seen because its shadow is obscured by that of the femoral head

FIG 1532 f—Oblique view of the sound right hip The head is in the acetabulum

FIG 1532 g—Oblique view of the dislocated left hip The displaced femoral head with the large superoposterior fragment of the acetabular roof is superoposterior to the acetabulum

tibial pulses cannot be felt Simultaneous sensory disturbances are present within the area of the femoral nerve When and if the limb is flexed in the hip, the artery is opened again and the normal color quickly returns and the dorsalis pedis and posterior tibial pulses again are palpable With some fracture-dislocations of group IV (shearing off of a large posterosuperior bone wedge), and with all fracture-dislocations of group VIII (with fracture of the femoral neck), as well as with lacerations of the iliofemoral ligament, there is no "springy fixation" Reliable diagnosis then depends on the roentgenogram.

Questions We Should Ask Ourselves in Suspected Dislocations of the Hip in Order to Avoid Failures.

A General questions

1 Have I examined the patient for shock, especially in cases with concomitant injuries?
2 Have I noted the color and expression of the patient's face (pale, flushed, covered with sweat, expression of pain)?
3 Have I taken the radial pulse?
4 Have I taken the blood pressure?
5 Have I checked the dorsalis pedis and posterior tibial pulses?
6 Have I tested the patellar tendon reflex on the sound leg?
7 Have I checked both pupils as to their form and diameter as well as to their reactions to light and accommodation?
8 Have I tested the active motion of all joints in both lower limbs, starting with the toes and going up to the hip?
9 Have I tested sensibility in case of motor paralysis?
10 Have I, in case of simultaneous injuries to the arms, tested the active motion of all joints in both arms, starting with the fingers and going up to the shoulders?
11 Have I examined the whole body, including the head, posteriorly and anteriorly, as to injuries, discolorations and deformities?
12 Have I, in case of unconsciousness of the patient, tested the passive motion of all joints in their full ranges?
13 Have I written down all findings?

B Local questions concerning the hip joint

1 Have I asked about the past history and about the nature and details of the accident?
2 Have I observed any deformity of the region of the hip and of the limb, and have I stated its type (internal or external rotation, adduction or abduction, flexion or extension, and eventual protrusion of the dislocated femoral head)?
3 Have I noticed any discoloration of the dislocated limb (pale or cyanosed instead of normal)?
4 Have I looked for "springy fixation"?
5 Have I palpated the hip in order to try to recognize the dislocated femoral head either posterior to the greater trochanter or in the inguinal region?
6 Have I made a roentgenogram of the whole pelvis?
7 Have I positioned the pelvis exactly transversely and not obliquely to the longer axis of the X-ray table?
8 In cases of uncertainty have I made a lateral or an oblique roentgenogram?

TREATMENT OF PURE DISLOCATION OF THE HIP
(Group I)

In *reduction* and *treatment* of a dislocation of the hip the following things are needed.

1 A good level (*not* oblique) view of the whole pelvis
2 A board, about 2 m by 35 cm (fig 1533)
3 Two warm blankets, one for spreading over the board and the other for covering the patient.
4 A broad strap for fixing the pelvis (fig 1533)
5 A sheet for applying traction to the distal end of the thigh (fig 1533)
6 Local, spinal or general anesthesia (see Vol I/pp 118—122)

Treatment of Shock If in the initial examination one has found the patient to be in shock, which is especially frequent in patients with numerous concomitant injuries, one must of course combat the shock as quickly and effectively as possible before having roentgenograms made and before starting reduction This is frequently accomplished by warming the patient and by anesthetizing the various injured areas, as described in Vol I/pp 134 and 372 in two patients with dislocation of the hip and other serious concomitant injuries If those measures do not raise the blood pressure and slow the pulse, a transfusion of blood or plasma will be necessary. Roentgenograms must not be taken and reduction must not be started before shock has been effectively overcome

Comments Concerning Reduction It should be performed (1) early and (2) carefully Essential for success is immediate reduction on the day of the accident Reduction must be effected slowly, carefully, steadily and never jerkily, yet with adequate force In order to relax the muscles the hip and knee are flexed 90° To eliminate spasms resulting from pain, local or general anesthesia is usually used

Position of the Patient (fig 1533) He is arranged on the board (about 2 m by 35 cm) and covered with a blanket An ironing-board, which will be found in nearly every home, may also be used Then the pelvis is attached to the board by means of the strap The arms are fastened crosswise on the chest To prevent chilling of the patient, the trunk and the sound leg are covered Then the affected limb is flexed to right angles in the hip and the knee The sheet is folded to a sling and put round the "sick-side" thigh Then the surgeon, facing at right angles to the long axis of the patient, kneels down beside the patient With a dislocation of the right hip he puts his right knee, and with a dislocation of the left hip his left knee, into the hollow of the knee of the patient's dislocated limb The ends of the sheet are tied around the surgeon's sharply bent neck He should bend so far as to leave only a hand's breadth between his face and the knee of the patient

General Anesthesia As reduction is usually achieved within a few seconds or minutes, general anesthesia is most expedient As a rule we have used ethyl chloride (see Vol I/p 122), sometimes with addition of ether, or we have used carbon dioxide, Evipan or sodium pentothal So far we have not tried curare or any other muscle-relaxing drugs As a rule one can do without them

Local Anesthesia After having applied local anesthesia to the hip-joint in order to combat shock, one may try reduction under just this anesthesia. We have used local anesthesia 5 times in our 79 cases, 20 cc of a 2% Novocain solution was injected straight into the joint

With three cases reduction was effected without anesthesia It is important to know that My assistants, for instance, have reduced dislocations of the hip without anesthesia high in the mountains, transport of the patient being impossible because of the weather

Reduction of Dislocation of the Hip As soon as pain has ceased and the muscles have relaxed, the surgeon applies ventral traction to the limb flexed

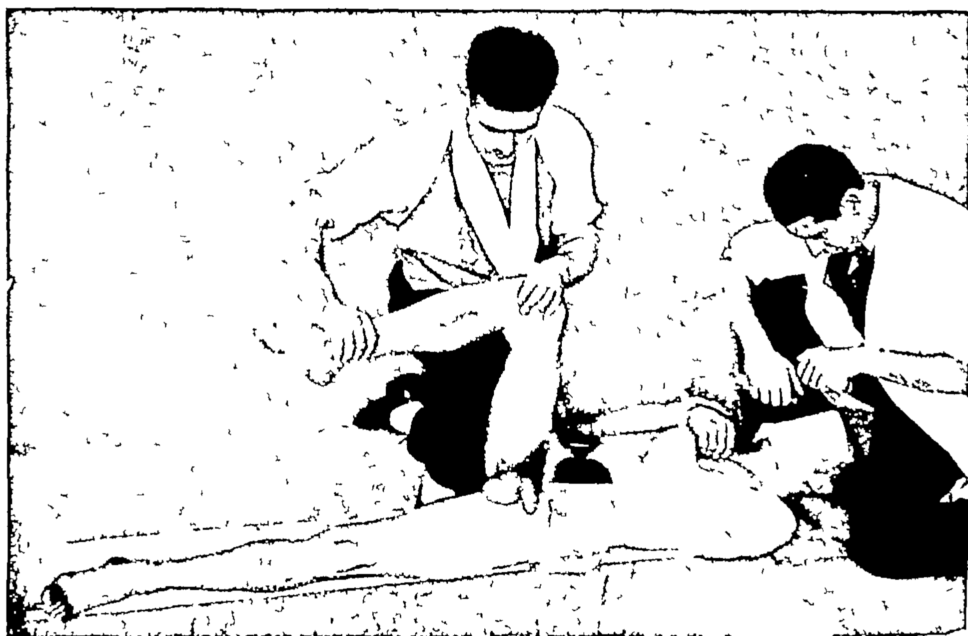


FIG 1533—Reduction of a dislocation of the right hip The patient is lying on a board For reasons of clarity the blankets covering the board and the patient have been omitted The pelvis is attached to the board by means of a strap, the arms are fastened crosswise on the chest A sheet is wrapped round the dislocated thigh above the knee Its ends are tied around the neck of the surgeon, who puts his right knee into the hollow of the patient's right knee In reality, the head of the surgeon should be only a hand's distance from the patient's knee As soon as the patient is completely anesthetized the surgeon raises his head, thus pulling on the sheet wrapped around the thigh This traction will be even more effective if the surgeon applies downward pressure upon the ankle of the patient, thus levering the thigh upward The femoral head will jump back into the acetabulum within a few seconds or minutes

at right angles in the hip and knee joints by raising his body, thus pulling on the sheet slung around his neck In addition, he applies slight dorsalward pressure on the patient's foot with his right hand in dislocation of the right hip and with his left hand in dislocation of the left hip, thus levering the tibia of the dislocated limb over his own knee as a fulcrum and pulling the femur ventrally This must be done very slowly and with adequate force, it must never be done jerkily Rotatory movements should be avoided, as the cartilage of the femoral head is easily peeled off by the acetabular lip After a few seconds

or minutes the head is felt to jump into the acetabulum, sometimes doing quite audibly The joint which previously showed "springy fixation" can nc be moved freely and in all normal directions In a case of ours in which the was upward displacement of the femoral head by its full diameter (fig 1530/III traction had to be applied for 35 minutes, since longitudinal traction in t long axis of the body necessary to the proper reduction of this type dislocation had not been applied previously

As no violent force is applied with this type of reduction, and abductory, adductory and rotatory movements are avoided, the torn musc and ligaments are not exposed to any further injuries and the cartilaginc cover of the femoral head is protected from being peeled off Neither fractures of the femoral neck or the femoral shaft occur, as have bc described with other methods of reduction Henry, Arnold and Bayur in 1934 reported 21 cases with 1 fracture of the femoral head, 17 of t femoral neck, and 3 of the femoral shaft which occurred during reducti 19 of these 21 cases were cases of delayed reduction

Traction by means of the sheet sling proximal to the knee joint m be especially gentle If ventralward traction is applied only by lever through dorsalward pressure distally on the leg bent at right angles o the surgeon's knee, and if, moreover, strong rotatory movements performed, the ligaments of the knee joint may be seriously affected The f that reduction can be effected solely by traction with the sheet faster above the knee joint has been proved in a patient who had sustained, ap from an anteroinferior dislocation of the hip and a vertebral fracture, open fracture of the ipsilateral limb just below the knee Tibial leverage the thigh could, therefore, not be applied Yet reduction was easy with h (see Vol I/p 372) The same method of reduction was also successful in t other cases of ours with dislocation of the hip in association with fract of the ipsilateral lower leg

During the war I was sent a patient with dislocation of the hip to whose injured l someone had applied traction for three hours by means of a sling just proximal to the an the hip and knee joints both being extended Reduction had not been accomplished, but pressure of the sling had caused a hand's-breadth-wide circular necrosis of skin and tend making amputation of the lower leg necessary later on Reduction of this dislocation easily performed within nine seconds in the way described above, hip and knee joints b kept flexed, although the dislocation had occurred 13 days earlier

This method of reduction can be used with all posterior dislocation a surprisingly enough, with antero-inferomedial ones as well It failed first in a case of anterolateral dislocation and was then successful only af the dislocation had been transformed into a posterior one Wittmoser [2] described that case

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[1] Henry, K and Bayumi, N Fracture of the femur with luxation of the ipsilateral British J Surg 22 204, 1934

[2] Wittmoser, R Eine ungewohnliche Huftverrenkung Beitr klin Chir *176* 583— 1947

Reduction of Dislocation of the Hip with Severe Cranialward Displacement. (Fig 1531/III b) In the rare cases of dislocation with severe cranialward displacement of the femoral head, longitudinal traction with only slight flexion of the hip must be first applied in the longitudinal axis of the body in order to pull the femoral head down dorsal to the acetabulum Only when roentgenograms show the femoral head to have been pulled down to the level of the acetabulum should hip and knee be flexed at right angles for applying the method of reduction shown in figure 1533.

Reduction of Anterolateral Dislocation (figs 1528 and 1529 c) This rare dislocation is caused by abduction and external rotation leading to a so-called "luxatio obturatoria" Through further external rotation the femoral head, leaving the region of the obturator foramen, is moved anterior to the acetabulum and the greater trochanter slips into the acetabulum This mechanism is indicated by the position of the femoral artery lateral to the femoral head and neck Pressure of these structures on the artery causes the limb to be pale and pulseless.

In order to reduce this anterolateral dislocation one must first transform it into a luxatio obturatoria by flexing the extended leg, rotating it internally and abducting it One can best make this mechanism clear by doing such a "reduction" on a skeleton As soon as the luxatio obturatoria has been re-established, the method of reduction shown in figure 1533 can be applied

Reduction According to Stimson[1] *and Deshanelidze*[2] The patient lies prone on a table which has been padded with a blanket The injured limb, slightly supported, hangs down so far over the edge as to be flexed at right angles in the hip joint. Sometimes reduction is effected simply by the weight of the limb itself Otherwise the knee of the injured limb must be flexed at right angles, one of the surgeon's hands put into the popliteal fossa and used to exert downward (ventral) pressure until reduction occurs The positions of the hip and knee joints in relation to the body are the same as in figure 1533 This method has the great advantage of making anesthesia frequently unnecessary Deshanelidze reports that in 9 out of 37 cases reduction was achieved without anesthesia

Only when a detached posterior lip of the acetabulum was displaced into the acetabulum in the process of reduction have I seen *reduction obstructed* (see page 1104 and figure 1530/III b)

Testing Mobility of the Hip joint After reduction, mobility of the hip joint is tested first If reduction has been successful, hip motion will be free

Testing Stability Hip stability is tested by trying to displace the femoral head dorsally with the hip joint flexed at right angles If such displacement can be accomplished in a case of fracture-dislocation, the hip must be immobilized in extension or internal fixation must be performed

First Roentgen Check After attempted reduction one should make another roentgenogram, preferably a view of the whole pelvis, to see whether

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[1] Stimson "Fractures and Dislocations," Philadelphia, Lea and Febinger, 1910

[2] Deshanelidze "Luxationen des Huftgelenkes und ihre Einrenkung in Bauchlage des Kranken," Arch klin Chir *130* 565, 1924

reduction was successful and especially to allow recognition of any bony injuries which, because of the abnormal overlying shadows in the pre-reduction roentgenograms, sometimes cannot be accurately made out.

Position of Patient After Reduction. After roentgen demonstration of adequate reduction, the patient is put to bed with a pillow under the knee on the affected side. Since in simple dislocations of the hip without fracture of the posterior margin of the acetabulum or of the acetabular roof there is no danger of a redislocation of the head of the femur, neither immobilization in plaster nor traction is required.

Exercises. After 2 or 3 days the patient is asked to move the hip-joint actively. *This active motion must not cause him any pain.* After 3 to 10 days the patient is allowed up on the condition that this causes *no pain whatsoever.* Our 24 patients with simple dislocations of the hip without other concomitant injuries to their lower limbs have on the average got up on the 9th to the 10th day.

Duration of Treatment. Our 24 patients with simple dislocations of the hip without concomitant injuries on the average spent 10 days in the hospital and received ambulatory treatment for 42 days. As a rule they returned to hard work after 53 days.

Energetic massage and forcible passive movements must be avoided, since they may cause such grave complications as ossifications of the muscles and ligaments, arthrotic changes and necrosis of the femoral head, as well as persistent osteoporosis (see Vol. I/pp. 60—69).

Early Weight-Bearing. Many surgeons warn against early weight-bearing because they fear damages to the head of the femur with possible necrosis. In 43 simple dislocations of the hip, in 7 with associated chip fracture of the capsular insertions and in 10 with associated fracture of the posterior margin of the acetabulum, of which 36 cases have been observed for more than 5 years, I have seen necrosis of the femoral head only once (figs. 1534, 1535), i. e., in a 17 year old patient who had simultaneously suffered a compound fracture of the contralateral femur and a compound fracture of the skull and accordingly had been forced to lie in bed for 10 weeks. Thus he had put no weight on the hip. Since femoral head necrosis was in this case bilateral it was perhaps most reasonably attributed to a general disturbance, of perhaps a hormonal character, and not to the dislocation of the one hip. *In those patients with simple dislocation of the hip who have started bearing weight early I have never seen avascular necrosis and collapse of the head of the femur.* I wish particularly to emphasize this, because during the last years it has repeatedly been suggested that, in order to avoid head necrosis, every patient with dislocation of the hip should be treated for several months after reduction either by traction or in a big thoracopelvic hip-spica including the sound limb, or in a weight-bearing splint.

Second Roentgen Check. Three weeks after reduction an anteroposterior roentgenogram of the whole pelvis should be taken. By this time eventual ossification of the muscles is already detectable (figs. 1536, 1539).

The origin, prevention and treatment of traumatic myositis, of arthrotic changes and of avascular necroses of the femoral head are described on page 1119



1534, July 13, 1935



1535, July 13, 1935

FIGS 1534, 1535—Necrosis of the femoral head with fragmentation on the right and arthrotic changes on the left side four and a half years after a posterosuperior dislocation of the hip (luxatio iliaca) which had been reduced gently and at once Anteroposterior view (fig 1534) and lithotomy view (fig 1535) The marginal exostoses are particularly conspicuous in the lithotomy view In the anteroposterior view the cranial part of the joint "space" appears greatly diminished on account of the atrophy of articular cartilage in the cranial part of the femoral head In the lithotomy view the joint "space" does not appear diminished, because here the posterior and anterior parts of the femoral head are seen These changes have developed although the patient had been in bed for 10 weeks for a *compound fracture* of the left femur Walking was completely normal Two years later there was pain and limping on the right side Mobility reduced in both hips, crepitation on both sides Pain in the right hip only, left hip free from pain in spite of roentgenographic changes Flexion contracture of the hip and severe lordosis Five years later a bony ankylosis developed and because of it pain disappeared (case 3 of Obwegeser and case 1 of Trojan)

Questions We Should Ask Ourselves in Order to Avoid Failures in Treating Simple Dislocations of the Hip

1 Have I treated any existing *shock* before the roentgenograms and before the reduction?
2 Have I in treating the shock promptly warmed the patient with warm blankets, hot drinks and by "baking"?
3 Have I used local anesthesia in treating any shock?

4 Have I, upon failure of the warming and the local anesthesia, given blood or plasma at once?
5 Have I, after treatment of shock, made an anteroposterior roentgenogram of the whole pelvis with the pelvis neither tilted nor rotated?
6 Have I made oblique or lateral roentgenograms?
7 Have I prepared everything for anesthesia (see Vol I/page 122)?
8 Have I prepared everything for the reduction before beginning the anesthesia (board, two blankets pelvic straps, sheet, etc , as in figure 1533)?
9 Have I placed a blanket on the board?
10 Have I fastened the pelvis properly with the strap (fig 1533)?
11 Have I tied the hands well on the chest (fig 1533)?
12. Have I covered the trunk and the sound limb well to protect them against cooling?



July 13, 1935

FIG 1536—Slight ossification of the muscle 5 years after a luxatio obturatoria on the right side which had been reduced after 3 days The ossification has developed caudal to the joint where the dislocated femoral head lay in the torn muscle for 3 days The ossification was visible on the roentgenogram as a cloudy shadow of the same size and shape just three weeks after the injury Flexion restricted by 10° All other movements actively free through full range No complaints (case 2 of Obwegeser and 36 of Trojan) After 22 years the ossifications have slightly increased and flexion and rotation are reduced by a few degrees

13 Have I flexed the hip and knee joints at right angles to relax the iliofemoral ligament?
14 Have I tied the folded sheet firmly enough round the dislocated thigh just proximal to the knee?
15 Have I tied the sheet as tightly about the reducing surgeon's neck so that his face was not farther than a hand's breadth away from the patient's knee?
16 Have I pulled slowly and gently, with vigor, but avoiding jerky movements?
17 Have I refrained from rotational strains during the reduction?
18 Have I in severe cranialward dislocation of the femoral head (fig 1530/III b) first applied traction in the axis of the body in order to pull the head down caudal to the acetabulum?
19 Have I in this type of dislocation made a roentgenogram after the

longitudinal traction in order to ascertain the position of the femoral head?

20 Have I converted an anterolateral dislocation (figs 1528 c and 1529 c) into a luxatio obturatoria and have I reduced it then by the usual method with flexion, internal rotation and abduction?

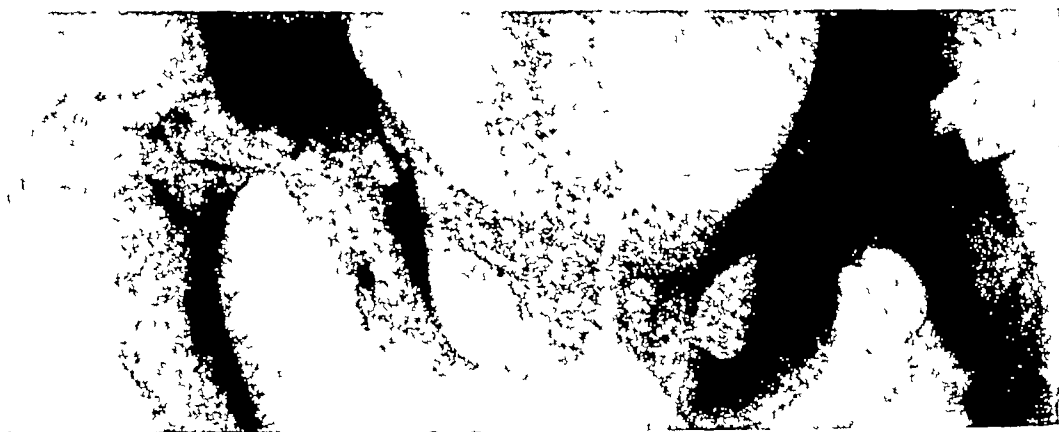
21 Have I tested the mobility of the hip joint after the attempted reduction?

22 Have I examined the stability of the hip joint after the attempted reduction?

23 Have I then made an anteroposterior roentgenogram of the whole pelvis without tilt or rotation?

24 Have I refrained from using a plaster cast or traction in after-treatment?

25 **Have I refrained from using massage and passive motion?**



April 27, 1931

FIG 1537—A six month old posterosuperior dislocation of the hip (luxatio iliaca) in a 47 year old farmer who had been knocked down by his cart Since he felt pain (referred) in the knee, the surgeon applied a plaster cylinder more or less immobilizing the knee joint for 6 weeks He could walk only with difficulty with two crutches The acetabulum is empty The femoral head is displaced cranially, dorsally and laterally by $^2/_3$ of its diameter, and the shaft of the femur is strongly adducted and internally rotated The lesser trochanter is not visible The density of the head of the femur and the greater trochanter is greatly reduced From the tip of the greater trochanter a bony spur extends towards the pelvis A shadow of calcium density is visible close to the empty acetabulum

26 Have I asked the patient on the 2nd or 3nd day to begin to move the hip joint actively, provided that there was no pain?

27 Have I allowed the patient to get up on the 3rd to the 10th day, *provided that no pain was felt?*

28. Have I had new roentgenograms made after 3 weeks and at the end of the treatment?

29 Have I told the patient at the end of the treatment to report immediately when and if pain should be felt in the hip later on?

30 Have I, in a fatal case, opened the hip joint in order to see changes in the joint?

31. Have I then made sections of the femoral head in the frontal plane to ascertain whether depressed fractures of the cancellous framework had occurred (see page 1121)?

OLD DISLOCATION OF THE HIP

If a dislocation of the hip is for some reason not diagnosed immediately, it is as a rule still possible to do the usual closed reduction only within the first four weeks In the second month one should, in the most frequent postero-superior dislocations, pull the femoral head caudally to the level of the acetabulum by skeletal traction (fig 1604 a) before attempting reduction



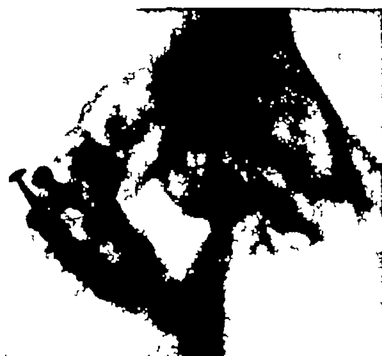
1538, May 5, 1931



1539, June 6, 1931



1540, November 6, 1933



1540 a, February 14, 1953

FIG 1538—Check roentgenogram re figure 1537, after eight days of continuous skeletal traction exerted above the knee with a weight of 15 Kg The head of the femur has been pulled down to the level of the acetabulum but still lies behind it

FIG 1539—Check roentgenogram re figures 1537, 1538, four weeks after open reduction and after removal of the plaster-cast The head of the femur is in the acetabulum The joint "space" is diminished in its cranial part The bony spur does not extend medially and caudally but rather medially and cranially, towards the pelvis The greater trochanter is fixed by three stainless steel nails

FIG 1540—Check X-rays re figures 1537—39, after two years The joint "space" is narrowed in its cranial part The femoral head is of normal shape and normal density Ossification of the muscle has considerably increased The mobility of the hip joint amounts to only a few degrees The limb is adducted 20° Walking is painful and possible only with a stick Though the condition is much better than before operation, walking would be better and completely painless with an arthrodesed hip

FIG 1540 a—Check X-ray re figures 1537—39, after 22 years, Ossification has greatly increased both cranially and caudally from the hip joint Owing to this, ankylosis has developed by extra-articular ossification The joint is stiff and painless The adduction contracture has increased The shape of the femoral head is normal

(figs 1537, 1538, 1541, 1542) Reduction may thus be possible even in the second month As a rule, closed reduction later than this is impossible, although isolated cases of late reductions of hip dislocations, chiefly antero-inferior ones, have been reported In dislocations of the hip more than two

months old one should refrain from attempting closed reduction, because it may cause fracture of the head, neck and/or shaft of the femur

Since without reduction of the dislocation the usefulness of the limb is poor (figs 1537—1546) because of the marked and usually increasing contractures one should try to do something to remedy the situation. At present the four following methods of treatment are available to us.

1 Pertrochanteric subcutaneous osteotomy,
2 Pertrochanteric open osteotomy and fixation with nail and plate,
3 Open reduction with subsequent arthrodesis, and
4 Arthroplasty

In selecting the method to be used in any specific case, the general condition, *the age and the profession of the patient must be taken into account* With pertrochanteric osteotomy and arthroplasty the hip joint remains mobile, though with a limited range Consequently the patients can sit comfortably and are able to put on their shoes and stockings without help But usually they cannot walk very far and they frequently have pain If one succeeds, however, in obtaining a solid bony arthrodesis in good position, i e, with mid-rotation, flexion of 15° to 20° and without considerable abduction, the patient is usually able to walk well even for long distances without marked limping and absolutely without pain These patient can walk or stand all day If they are young, they are even able to engage in various sports, e g, mountain-climbing and skiing (figs 1557—1567) Sitting is somewhat difficult and they can put on their shoes and stockings without help only if they are able to flex the knee joint entirely normally By using Neubauer's tongs, however, patients with ankylosed hips are able to put on shoes and stockings even if flexion of the knee is limited Arthrodesis is to be recommended to patients who must walk and stand a great deal

In the past we have generally performed **pertrochanteric subcutaneous osteotomy** if the joint was not stiff and the head of the femur was not displaced too far cranially Before the anesthesia is begun, slings are put about the ankles Then under general anesthesia a Steinmann pin to be used as a guide is driven transversely into the femur of the supine patient 4 to 5 cm below the tip of the trochanter and a roentgenogram is made in order to check the level of the pin A 3—4 cm longitudinal incision is then made through skin and fascia at the level of the lesser trochanter We expose the bone and insert a chisel 4 cm broad, turn it by 90° into the transverse plane as soon as it touches the bone and osteotomize the femur just cranial to the lesser trochanter The wound is closed by two catgut or wire sutures, the Steinmann pin is removed, and the wound is covered with a sterile dressing Then flexion, adduction and internal rotation deformities are corrected The patient is laid on an extension table as in figure 1577 The pelvis should be exactly straight, without tilt or rotation The operated limb is abducted only so far that a shortening of 1 to 2 cm remains Shortening is determined by putting the sound limb over against the operated limb, the former secured to the table. With shortening of over 5 cm the compensation by abduction should not exceed 4—5 cm and the remaining shortening should be taken

care of with a shoe lift As soon as the operated limb is properly positioned, slings are put round both ankles Then anteroposterior and lateral roentgenograms are made, and if all is well a thoracopelvic hip spica to be left for 8 weeks is applied as in figures 1627—1640 but with much less abduction and in mid-position rather than internal rotation As the wound is very small, a walking-caliper may be applied 7 or 8 days later and the patient allowed to get up and to walk around Since the osteotomy requires only a few minutes and involves essentially no loss of blood it is a comparatively minor operation among those used on the hip

Currently we prefer **open V-shaped pertrochanteric osteotomy and fixation with nail and plate.** The patient is put on an extension table (fig 1577 or 1701) and the trochanteric region is exposed The bone is divided in V-shape by a chisel at the level of the lesser trochanter Then adduction, flexion and rotation are corrected The two fragments are joined by a three-flanged nail and attached plate as in figure 1879 The V-shaped osteotomy is preferable to the transverse osteotomy because bony union is more certain and occurs earlier.

Arthrodesis of the Hip. In the past we removed the cartilage from the femoral head and the acetabulum during the procedure for open reduction, then after reduction we applied a plaster cast for 3 months As partial avascular necrosis of the femoral head usually develops after excision of the capsule (and with it of the nutrient vessels), bony ankylosis requires 1 to 2 years Therefore adduction, flexion and external rotation contractures often developed formerly after the comparatively short period of immobilization (figs 1540 a and 1546 a) Consequently we now drive two long three-flanged nails close to each other across the joint after excision of the cartilage and reduction These we leave for two years or permanently (fig 1565 g) The joint-space we fill with bone chips

Preparation for Operation In old dislocations of the hip, the head of the femur is generally very high, as in figures 1537, 1541 and 1543 Owing to the greatly shortened muscles, the reduction is then very difficult In order to facilitate the reduction, we first get the femoral head down to the level of the acetabulum Since comparatively heavy traction is reqired for this, we insert the pin or the wire proximal to the knee The limb is placed on a Braun splint (fig 1604 a) and is first subjected to traction of 10 Kg After two or three days the traction is increased to 15 Kg and a roentgenogram is made The contractures are usually overcome in eight to ten days (figs 1537, 1538 and 1541—1544) Procaine penicillin is given the night before operation and is continued until the patient has been entirely afebrile for at least two days

Operation To combat the generally grave shock caused by the operation, everything needed for blood transfusion must be prepared in advance The patient is put on his sound side and the involved femoral head is exposed either by a posterior oblique incision or by a big curved incision Usually the acetabulum is no longer visible because it is filled with heavy scar-tissue With removal of this scar-tissue by careful excision with scalpel and scissors, the occasionally intact cartilage is exposed The cartilage is now removed

from the femoral head and from the acetabulum, with parts of the subchondral bone, until cancellous bone is completely exposed By traction on the limb with knee and hip flexed at right angles, by external rotation and by insertion of a bone-lever, one is then usually able to replace the head of the femur in the acetabulum Then, after insertion of a drainage-tube, the wound is closed

If his general condition is good, the patient is placed on the screw traction apparatus as in figures 1701 and 1702 Then through a lateral incision a three-flanged nail 16 to 17 cm long is driven through the trochanter and the femoral neck as far laterally as possible into the acetabulum The operation is



1541, September 7, 1934 1542, September 17, 1934 1543, July 3, 1935

FIG 1541—Four week old posterosuperior dislocation of the hip in a 12 year old boy who had been run over by a heavily loaded straw wagon Owing to a 20 cm long avulsion of the skin on the lateral and anterior side of the knee, which extended to the joint capsule, he was taken to the hospital There the wound was sutured The dislocation of the hip was not recognized The wound became septic After 4 weeks the patient was brought to the Accident Hospital The acetabulum is empty, the head of the femur is displaced cranially and posteriorly by its own width, and the shaft of the femur is adducted and internally rotated

FIG 1542—Check roentgenogram re figure 1541, after continuous wire traction exerted above the knee with a weight of 5 Kg for 10 days The femoral head has been pulled down to the level of the acetabulum but still lies posterior to it Closed reduction attempted at this time failed As the knee wound suppurated, open reduction was not possible Since the wound did not heal, wire traction was removed and the boy was discharged home to remain until the wound closed

FIG 1543—Check roentgenogram re figure 1541, after 10 months The femoral head is displaced even farther cranially, posteriorly and medially than on September 7, 1934 Calcium content of the acetabulum and the trochanteric region is diminished The femoral head is crushed and sclerosed although it had not borne weight

carried out in the same way as is that for nailing of a fracture of the neck of the femur (see page 1317) The limb should be in mid-rotation, 15°—20° flexion, and only a few degrees abduction After the operation the limb is placed on a Braun splint or a pillow After 24 hours the drainage-tube is removed

If reduction has caused grave shock the limb is placed on a Braun splint with traction of 5 to 6 Kg on the supracondylar nail (which had not been removed) and the limb is slightly externally rotated The nailing for the arthrodesis can then be done two or three weeks later



1544, July 17, 1935



1545, October 9, 1935



1546, June 5, 1936



1546 a, February 14, 1953

FIG 1544—Check roentgenogram re figure 1543, after open reduction By continuous traction which had to be increased up to 15 Kg, it was possible after 14 days to get the femoral head down to the level of the acetabulum Through a curved skin incision the greater trochanter was chiseled off and lifted upwards with the attached muscles. The acetabulum was unrecognizable The dense fibrous tissue was removed with scissors and scalpel so that the cartilage was finally exposed The cartilage on the femoral head had been severely damaged in its cranial part After the reduction a rubber drain was inserted, the shadow of which can be seen superimposed upon that of the lower part of the neck The trochanter was fixed by two nails After this a plaster cast was applied which was left for four weeks

FIG 1545—Check roentgenogram re figure 1544, after 3 months The cranial part of the femoral head has been crushed Calcium content of bone almost normal No ossification of muscles or ligaments

FIG 1546—Check roentgenogram re figure 1545, one year after open reduction and two years after dislocation The femoral head is broadened as in Perthes' disease Still no ossification of muscles or ligaments visible The limb is adducted and internally rotated Mobility only a few degrees Gait limping but painless

FIG 1546 a—Check roentgenogram re figure 1541, after 19 years The head of the femur has disappeared The stump of the neck is rounded off and in the acetabulum there is a rather wide and sharply-demarcated joint "space" Severe adduction contracture of the limb Hip joint stiff In such cases an arthrodesis or arthroplasty should be performed after reduction

Exercises are carried out just as in nailed fractures of the femoral neck (see page 1341) Three to four weeks after the operation the patient is able to get up without immobilizing bandage

Figure 1565 e shows the result of such an arthrodesis

Arthroplasty. (Figs 1565 a—c) Since 1948 we have occasionally used Judet's acrylic prosthesis in necroses of the femoral head following dislocations of the hip and fractures of the neck of the femur We do not have any personal experience with Smith-Petersen's cups In treating our next case of old dislocation of the hip we plan to use a femoral head prosthesis provided that it seems at the time appropriate, i e, if the patient has no myositis ossificans Results of such an operation are shown in figures 1565 b, c

TREATMENT OF DISLOCATION OF THE HIP WITH FRACTURE OF THE POSTERIOR LIP OF THE ACETABULUM (Group III, Figure 1530/III a and b)

Complications In group III a (figs. 1530/III a and 1546 d) there is danger of redislocation if, as rarely occurs, the joint is not stable after reduction In group III b (figs 1530/III b and 1546 b and c) there is danger of interposition of a fragment sheared off from the posterior lip of the acetabulum and which



June 25, 1948 June 25, 1948 August 2, 1952

Fig 1546 b left—Luxatio iliaca eversa with two fragments sheared off from the posterior lip of the acetabulum The femoral head is in external rotation, 48 mm cranial to the acetabulum The fragments have remained at the level of the acetabulum and are not, as is usually the case, displaced cranially together with the femoral head (fracture-dislocation, group III b) Case of 33 year old unskilled worker buried by collapsing walls

Fig 1546 b, center—Reduction was attempted but led rather to interposition of the fragments in the joint The joint "space" is considerably wider than normal and the position of the head is abnormally lateral The fragments are now situated between the head of the femur and the lateral lip of the acetabulum Therefore, arthrotomy was done through a curved incision and the fragments were removed Patient got up after 27 days

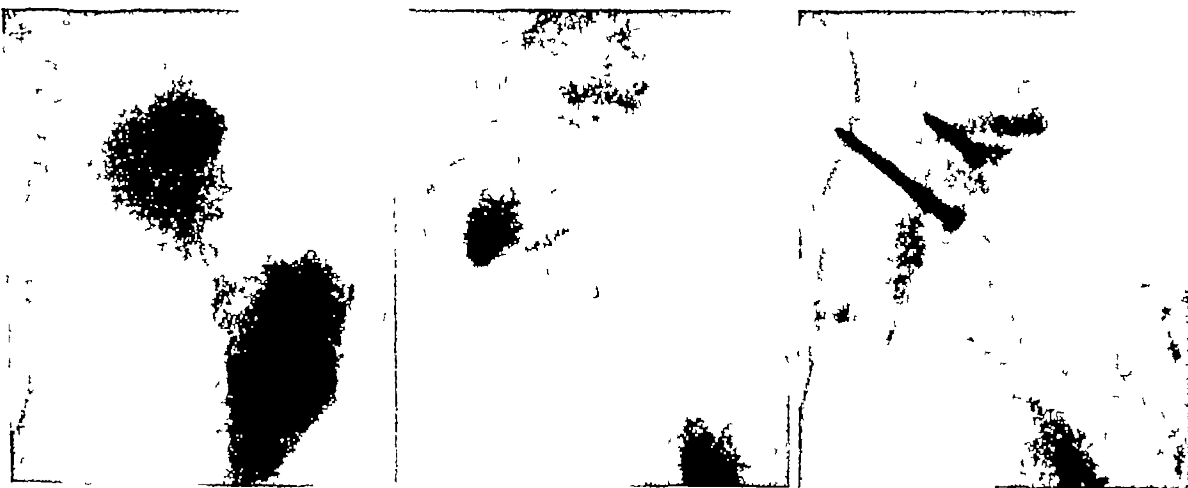
Fig 1546 b, right—Condition after four years The width of the joint space is normal There are no arthrotic changes and no necrosis of the femoral head The shadow cranial to the greater trochanter is due to the dissection at operation Mobility of the hip slightly reduced Some discomfort in the joint after strenuous activity (case 59 of Trojan)

has remained attached to the periosteum at the level of the acetabulum and has not been displaced cranially together with the femoral head

The *mechanism* of this fracture-dislocation of the hip is described on page 1075 and is sketched on figure 1546 d We have seen it in 10 of our 79 cases

Reduction is performed in the same way as in simple dislocation of the hip (see page 1089) In cases belonging to group III b, with the femoral head displaced far cranially (figs 1530/III b and 1546 b and c), we must not forget to exert traction first in the long axis of the body in order to pull the head of the femur caudally to the level of the acetabulum before beginning the standard reduction maneuvers (see page 1092)

Examination of Mobility and Stability After reduction we check to see whether the hip-joint is freely mobile and whether the femoral head remains in



January 20, 1951 February 12, 1951 February 20, 1953

FIG 1546 c, left—Luxatio iliaca with irregular posterior lip of the acetabulum in a 33 year old truck driver The femoral head is 17 mm cranial to the roof of the acetabulum and is in internal rotation (Fr-DH, group III b) Caused by car collision in which he also lost his right arm

FIG 1546 c center—Attempted reduction resulted in interposition in the joint of a fragment of the posterior lip of the acetabulum with attached periosteum The fragment lies between the femoral head and the roof of the acetabulum The femoral head is displaced cranially The joint "space" is 11 mm wide As the joint was unstable, traction was applied Arthrotomy was done after 23 days through a posterior oblique incision, the head was dislocated and the fragment attached to the periosteum was removed from the joint The teres ligament had been torn from its origin The cartilaginous surface of the femoral head was intact Fixation of the 4×2×1 cm fragment was afforded by two screws, and the patient got up 21 days after operation

FIG 1546 c, right (February 20, 1953)—Condition after two years The width of the joint space is normal No myositis ossificans, no necrosis of the head, no arthrosis

the acetabulum when the hip and knee are flexed to right angles and pressure is exerted on the knee in the long axis of the femur

First X-ray Check After reduction a roentgenogram of the whole pelvis is made If we see in a case in group III a that the posterior margin of the acetabulum remains displaced dorsally and cranially, as in figure 1546 d, we

can leave it in this position, because according to our follow-up examinations such displacement does not cause any disturbance

Among the cases of group III b (fig 1546 b and c) it is a great deal more important not to miss an interposed marginal fragment in the joint. It is characteristic of interposition that the joint-space appears much wider on the injured side. Upon careful examination we see the displaced fragment between acetabulum and femoral head (fig 1546 b and c)

Treatment of Interposition of the Posterior Lip of the Acetabulum. The joint is exposed by a curved incision and by chiseling off the greater trochanter, or by a posterior oblique incision Then the interposed fragments, still connected to the periosteum, are pulled out and removed, provided they are small If a large fragment is involved, it is reduced and secured with a screw (fig. 1546 c).

Time of Operation. Operation should be done either on the very first day or after the 21st day Operations during this interval are often followed by the development of myositis ossificans with severe limitation of mobility. After operation the joint is generally stable

Second Check Roentgenograms Before we close the wound we make another roentgenogram in order that we may be as sure as possible that all fragments have been removed, that the eventual screwed-on fragment is in its proper place, and that the head of the femur is in the correct position in the acetabulum.

Positioning of the Patient with Stable Fracture-Dislocation of the Hip. The limb is laid flat in bed and is not placed upon a Braun splint, because with the hip in mild flexion on the splint there is a danger of redislocation of the femoral head

Positioning of the Patient with Unstable Fracture-Dislocation of the Hip with Associated Fracture of the Posterior Margin of the Acetabulum These patients are kept in traction for seven to eight weeks, as are those with fracture of the femur (fig 1604 a)

Prognosis is good if the dislocation is recognized and reduced on the first day. Among our cases we have seen no myositis ossificans, necrosis of the head or arthrosis (figs 1546 b—d)

TREATMENT OF DISLOCATION OF THE HIP WITH ASSOCIATED FRACTURE OF A BIG SUPEROPOSTERIOR BONE-WEDGE FROM THE ACETABULAR ROOF (Group IV, Figure 1530/IV)

Complication The following complications may occur in Group IV. (1) Redislocation, (2) Paralysis of the sciatic or peroneal nerve, (3) Myositis ossificans, (4) Necrosis of the femoral head, and/or (5) Arthrosis

Their *mechanism* is described on page 1075 and illustrated in figure 1564 e

Clinical examination is made in the same way as in simple dislocations of the hip (see page 1082).

Clinical diagnosis can be difficult because, if a large piece of the acetabular roof is sheared off, it may well be that the limb is not in the pathognomonic position and that there is no "springy fixation."

Roentgen diagnosis frequently presents major difficulties It happens occasionally that a fracture-dislocation of the hip is missed, although all its clinical symptoms and signs are present, simply because the roentgenogram shows the shadow of the posteriorly dislocated femoral head projected actually in superimposition but apparently within the acetabulum and because it is too little known that isolated fracture of the acetabular roof does not occur without concomitant dislocation of the hip (figs 1532 b—d and 15[illegible]7) The necessity of making roentgenograms of the whole pelvis and the technique of making oblique roentgenograms are discussed on pages [illegible] and [illegible]

In examining for fracture-dislocation of the hip we should ask ourselves the same questions as with simple dislocation of the hip (see page [illegible])

The roentgenogram of the entire pelvis must be studied with particular care lest in the presence of fracture of the acetabular roof a dislocation might be overlooked

Time of Reduction One should try to make the diagnosis on the first day and to reduce at once, because paralysis, myositis ossificans and necrosis of the femoral head frequently occur if reduction is delayed more than 24 hours

Reduction is performed in the same way as in simple posterior dislocations of the hip (see page 1089)

Examination of Stability If we push the femur dorsally while the knee and the hip are both flexed at right angles, the femoral head will [illegible] because of the instability of the joint

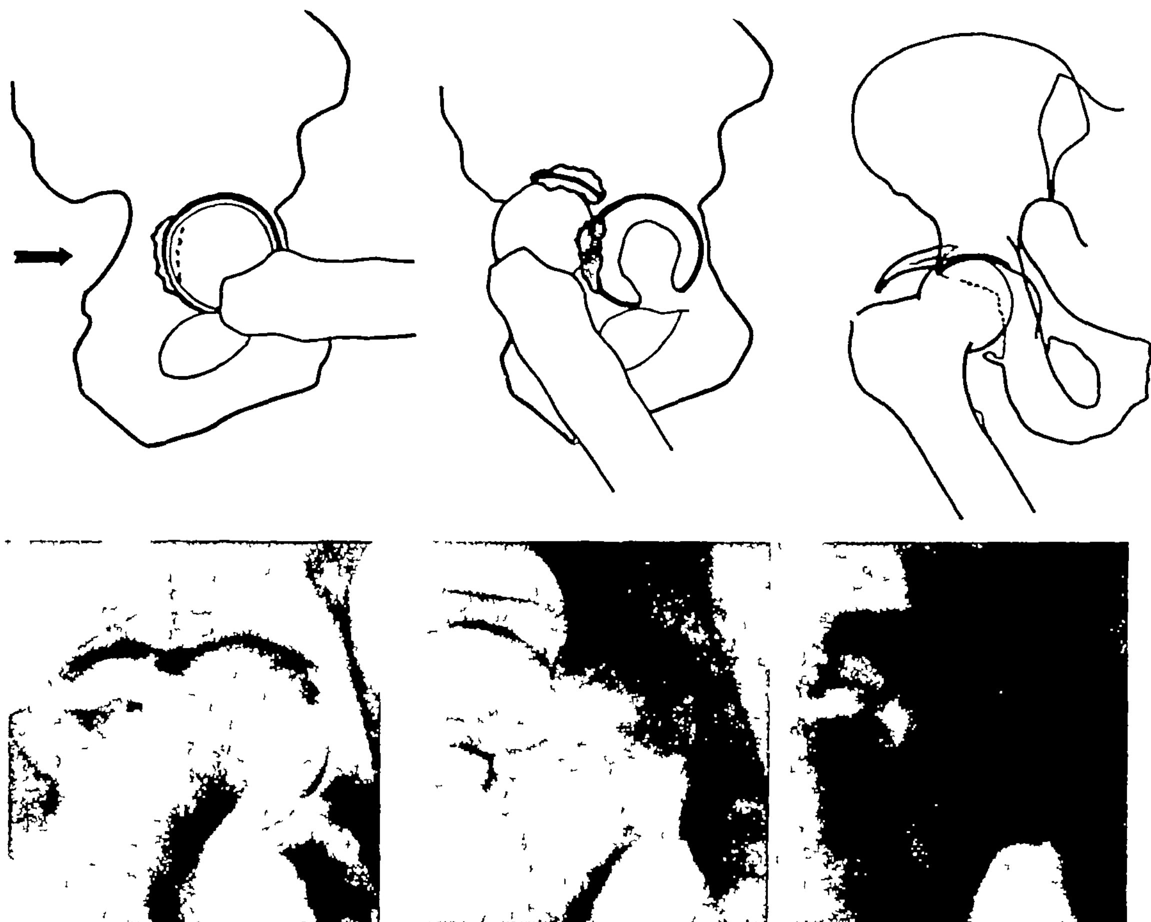
First Roentgen Check. After reduction a roentgenogram of the whole pelvis must again be made, and in doubtful cases an oblique view [illegible] order to ascertain whether the head of the femur is properly placed in the acetabulum and whether the fragment of the acetabular roof is well reduced

Immobilization If the fragment of the acetabular roof is well reduced one may apply a traction bandage and a plaster cast But if it remains displaced despite the attempted reduction, as in figure 1532 c—g, one should operate

Conservative Treatment of Acetabular Fracture by Traction If the fractured bone-wedge is well reduced, or if the bone-wedge is in an unsatisfactory position but the patient's general condition is bad, the simplest and most gentle treatment is with skeletal traction as in the treatment of fractures of the femur (figs 1604 a and 1606) with a weight equal to one-sixth to one seventh of the body weight A pin or wire should be inserted proximal to the knee and traction sufficient to produce a diastasis of 5 to 6 mm in the joint should be exerted with a view to relieving pressure on the damaged femoral head If the diastasis becomes wider than 5—6 mm the traction-weight should be reduced

Second Roentgen Check After one day, or at the latest after two days, new roentgenograms are made to confirm the proper position of the head and to show whether the reduced acetabular roof fragment has become subsequently displaced and whether traction is just strong enough to produce a diastasis of 5 to 6 mm between femoral head and acetabulum

Conservative Treatment of Acetabular Fracture in Plaster Instead of continuous traction we may also apply a thoracopelvic hip spica with hyper-



Sketched in June 1952

Fig 1546 d, top left—If the pelvis is suddenly and violently moved forward while the hip is flexed 90° and the femur is fixed at the knee, the head will shear off the posterior lip of the acetabulum The fracture line is marked by a heavy line

Fig 1546 d, top center—The head of the femur is dislocated cranially and dorsally and has torn and carried away the fragment from the posterior part of the acetabulum Lateral view

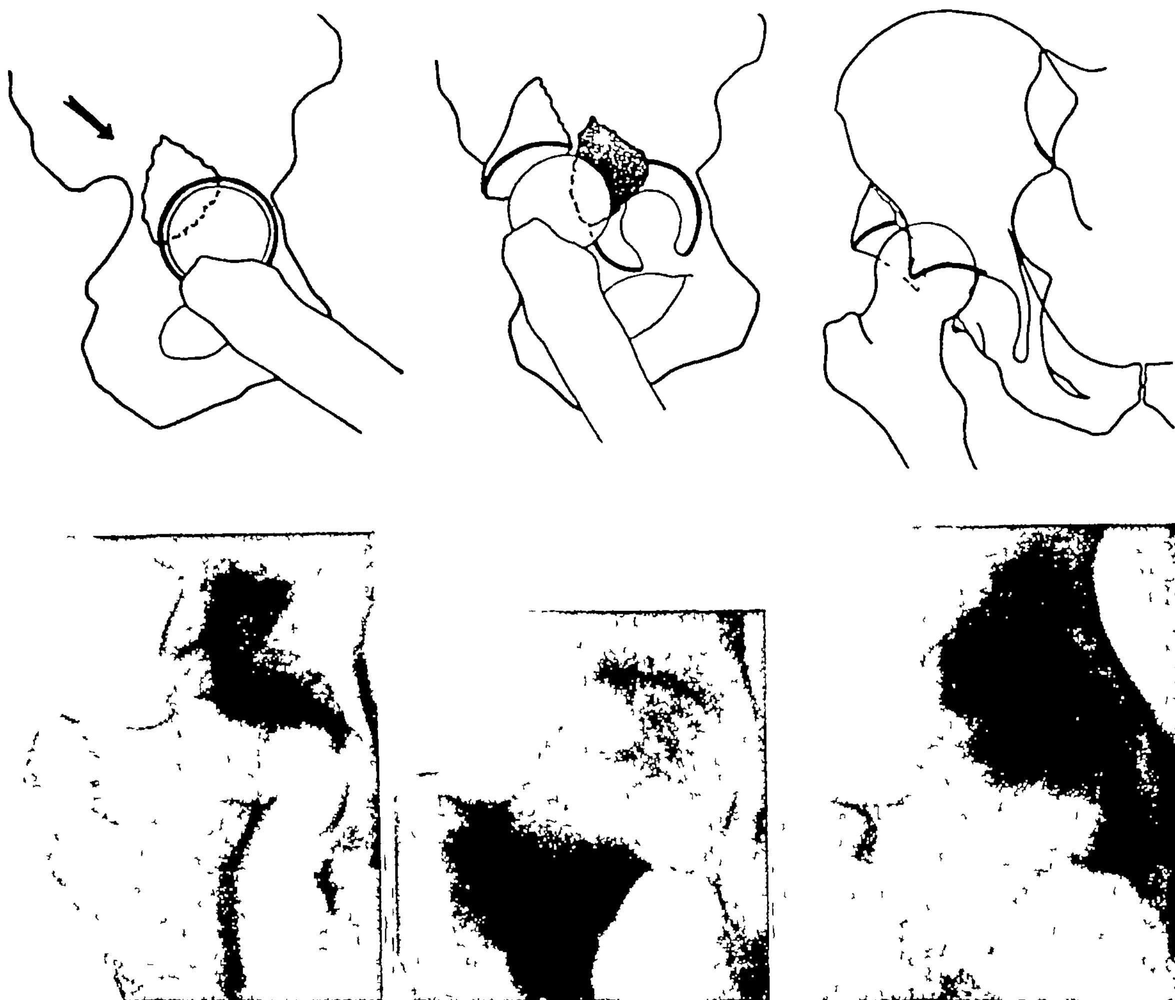
Fig 1546 d, top right—Anterior view of the fracture-dislocation (Fr-DH, group III a)

Fig 1546 d, bottom left (December 13, 1937)—Luxatio iliaca with fracture of the entire posterior margin of the acetabulum The femoral head lies at the back of the acetabulum and is displaced cranially so far that the joint space cannot be seen any more The big fragment is displaced upwards and laterally and is internally rotated (FrDH, group III a) Caused by a fall from a streetcar in a 63 year old metal-grinder

Fig 1546 d, bottom center (December 13, 1937) after reduction—The femoral head is in the acetabulum The width of the joint space is normal The fragment of the posterior acetabular lip has remained posteriorly and cranially to the acetabulum After reduction, traction for four weeks Patient got up on the 45th day

Fig 1546 d, bottom right (March 13, 1948, i e, ten years after the accident)—Width of joint space normal No arthrotic changes Calcification round the tip of the displaced fragment The defect on the posterior part of the acetabulum is clearly visible Walking free from pain Mobility of the hip slightly limited (case 51 of Trojan)

extension, medium abduction and midrotation as in figures 1627—1640 This treatment has a disadvantage in that pressure on the damaged femoral head is not relieved



Sketched in June 1952

Fig 1546 e, top left—The pelvis is suddenly thrust forward by a violent force while the femur is almost fully extended in the hip and fixed at the knee or at the foot The femoral head shears off the posterior margin of the acetabulum The fracture line is marked by a heavy line

Fig 1546 e, top center—The femoral head is dislocated dorsally and cranially and has torn and carried away the posterior part of the acetabulum

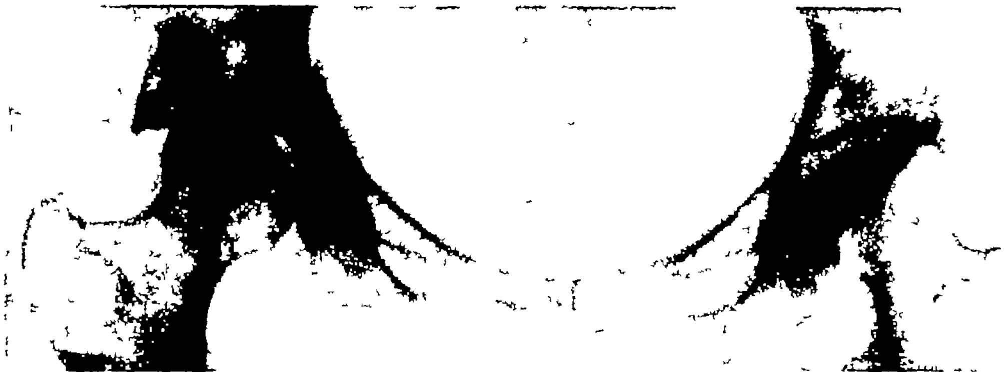
Fig 1546 e, top right—Anterior view of this fracture-dislocation Acetabular roof fragment and femur are displaced posteriorly, cranially and laterally and are internally rotated Because of this, the posterior wall of the pelvis appears as a sharp lateral margin of the fragment (Fr-DH, group IV)

Fig 1546 e, bottom left (August 22, 1944)—Luxatio iliaca, fracture of the posterior part of the acetabular roof The femoral head lies posteriorly and cranially to the acetabulum The big bone wedge lies slightly cranial to the head of the femur (Fr -DH, group IV) Case of a 45 year old crane-attendant, who was buried by collapsing walls Reduction was done a few days after the accident

Fig 1546 e, bottom center (October 17, 1944)—Eight weeks after the accident The femoral head is in the acetabulum, the sheared-off fragment is well reduced Width of joint space normal

Fig 1545 bottom right (September 28, 1935)—Thirteen months after the accident the cranial half of the femoral head shows increased density as a roentgen sign of necrosis The cranial cortex is crushed, the joint-space is narrowed Abduction and external rotation contracture Marked painful limitation of mobility in the hip, severe limp (case 65 of Trojan)

Time of Operative Treatment of Dislocation of the Hip with Concomitant Fracture of the Acetabular Roof As with interposition of fragments of the posterior margin of the acetabulum, the operation is permissible only on the very first day or after the 21st day, because operations performed



1547, July 19, 1934



1548, July 20, 1934 1549, October 10, 1944 1550, March 8, 1935

Fig 1547—Two day old fracture-dislocation in a 37 year old woman caused by car collision (Fr-DH, group IV) The femoral head is displaced posteriorly, somewhat laterally and cranially, so that it seems to touch the margin of the acetabulum Fracture-dislocations of this kind are easily overlooked and are taken for isolated fractures of the acetabulum The posterior cranial part of the acetabulum is fractured and displaced posteriorly, cranially and laterally Owing to the internal rotation of the femur, the fragment is also internally rotated Consequently the posterior wall of the fragment appears as a sharp, lateral margin The fragment is 30 mm high and is 12 mm cranial to the femoral head The acetabulum is also fractured and the crista terminalis is displaced somewhat medially

Fig 1548—Check roentgenogram re figure 1547, after continuous traction for 24 hours exerted by a pin driven through the tibial tubercle and with a weight of 12 Kg The femoral head lies exactly in the acetabulum The cranial part of the acetabulum has been pulled down A flake of bone lies behind the acetabulum

Fig 1549—Check roentgenogram re figures 1547 and 1548, after three months at the time of removal of the traction The cranial part of the margin of the acetabulum has united in the proper position The flake of bone formerly situated behind the neck of the femur now seems to lie behind the acetabulum Joint "space" slightly narrowed Calcium content of femoral head seems slightly reduced, but the united part of the acetabular roof, on the other hand, is markedly sclerosed

Fig 1550 Check roentgenogram re figure 1547, after eight months Calcium density of the acetabulum and the femoral head is normal except for a small spot in the cranial and lateral part which has a markedly reduced calcium content Walking is free from pain Active hip joint motion free in all directions

during this interval are often followed by myositis ossificans with severe reduction of mobility



1551, May 27, 1935



1552, May 27, 1935



1553, October 25, 1935



1554, June 5, 1936



1555, March 19, 1937



1556, February 10, 1953

FIG 1551 —Check roentgenogram re figure 1547, ten months later Joint space narrowed in its cranial part Calcium content of femoral head less than on March 8, 1935 Irregular bone structure Beginning depression at the cranial part of the head

FIG 1552 —Comparison roentgenogram re figure 1551 with patient in lithotomy position so that the femur is seen from the medial side Joint space normal in its cranial part with the limb so placed, the cartilage being preserved on the anterior wall of the femoral head though partly destroyed in the anatomically cranial part Calcium content reduced in the anterior part of the femoral head Patient limps always and has pain after long walks

FIG 1553 —Check roentgenogram re figure 1547, 15 months later Joint space has almost disappeared cranially Further crushing of the femoral head Marginal exostoses on the cranial part of the femoral head and on the acetabulum Patient limps considerably, joint mobility is strikingly good

FIG 1554 —Check roentgenogram re figure 1547, 23 months later The cranial third of the femoral head is very irregular and has a diminished calcium content The middle third is dense Arthrotic changes of the femoral head and the acetabulum have increased

FIG 1555 —Check roentgenogram re figure 1547, 32 months later Further crushing and flattening of the cranial third of the femoral head Joint space again slightly widened Arthrotic changes have increased Patient limps considerably Pain only when walking, not when standing, sitting or lying Mobility strikingly good, diminished by hardly one third

FIG 1556 —Check roengenogram re figure 1547, 18 years later The upper part of the femoral head has disappeared Joint space no longer visible Hip stiff Painless gait, without any considerable limp

Operative Treatment of Dislocation of the Hip With Concomitant Fracture of the Acetabular Roof If the sheared-off posterosuperior bone wedge cannot be reduced well it should be exposed operatively like a displaced posterior lip of the acetabulum (fig 1546 c), reduced and secured with a screw

Post-operative Treatment After operation one should continue with continuous traction to the end of the twelfth week as in conservative treatment (see page 1105), maintaining a diastasis of 5—6 mm in the hip-joint in order to relieve pressure on the injured femoral head

Check roentgenograms and exercises are as with fractures of the femur (see page 1265)

Results are good also with these fracture-dislocations of group IV if they are reduced on the first day Following delayed reduction one frequently sees changes as in figures 1546 e and 1553—1556.

Questions We Should Ask Ourselves to Avoid Failure when Treating Dislocation of the Hip with Fracture of the Posterior Lip of the Acetabulum or with Avulsion of a Large Superoposterior Wedge from the Acetabular Roof

After having asked and answered the questions on page 1094 relative to pure dislocation of the hip, one should ask oneself and answer the following also

1 Have I tested for stability or instability of the joint?
2 Have I remembered when interpreting the roentgenogram of the whole pelvis that isolated fractures of the acetabular roof with displacement do not occur in the absence of dislocation of the hip?
3 Have I recognized the interposition of a fragment or of fragments in the joint by diastasis existing independent of continuous traction?
4 Have I, if the joint is unstable and the patient's general condition is bad, applied continuous traction with a pin or wire in the femur?
5. Have I made a roentgenogram of the whole pelvis on the second day in order to make sure that the joint has been reduced and that there is a joint diastasis of 5 to 6 mm ?
6 Have I removed the interposed fragment from the joint, reducing it and securing it with a screw if it was large or removing it entirely if it was small and if stability of the joint was not thereby diminished?
7. Have I screwed on a marginal fragment if it did not reduce securely and well?
8 Have I done the operation only on either the first day or after the 21st day in order to avoid myositis ossificans?
9 Have I, after having screwed on the marginal fragment, applied adequate continuous traction to produce a diastasis of 5 to 6 mm in the hip-joint?
10 Have I made check roentgenograms of the whole pelvis every week or every other week?
11 Have I seen that exercises were performed regularly?
12 Have I avoided discontinuing traction too early, i e, before the 12th week?

TREATMENT OF DISLOCATION OF THE HIP WITH ASSOCIATED MARGINAL FRAGMENT OF THE FEMORAL HEAD (Group VI, Figure 1530/VI)

In our 79 cases of dislocation of the hip there have been 3 cases with marginal fracture of the femoral head, viz , posterosuperior in two and antero-inferior in one (fig 1530/VI). The mechanism of this injury has been described on page 1075 In each of our three cases the marginal fragment was left extra-articularly after reduction In one case severe arthrotic changes developed with considerable pain and limited mobility, in a second there developed slight arthrotic changes and in a third a necrosis of the head In the future we shall remove the marginal fragment immediately after reduction if the patient's general condition is favorable, i. e , if there are no indications of shock If there is still considerable pain in the hip despite this it is best to do later an arthrodesis or an arthroplasty (see figures 1565 a—1565 e and pages 1099 and 1102)

TREATMENT OF DISLOCATION OF THE HIP WITH ASSOCIATED DISPLACEMENT OF THE PROXIMAL FEMORAL EPIPHYSIS (Group VII, Figure 1530/VII)

Mechanism has been described on page 1075

Treatment of Recent Cases We consider it most expedient to remove the displaced epiphysis and to remodel of the hip joint using a femoral head prosthesis (see page 1102)

Treatment of Old Cases So far I have seen only two old cases In each of those I removed the displaced epiphysis and placed the stump of the femoral neck into the acetabulum In both cases contractures and pain developed later on In one case I found the femoral head behind the acetabulum to have become firmly united with the pelvis and the femoral neck so that an "extra-articular ankylosis" had developed Position of the limb was good Probably it would have been better to have left that situation undisturbed rather than to remove the femoral epiphysis

TREATMENT OF DISLOCATION OF THE HIP WITH ASSOCIATED FRACTURE OF THE FEMORAL NECK (Group VIII, Figure 1530/VIII)

Mechanism Among our 79 cases of dislocation of the hip there have been three posterior dislocations and one anterior dislocation with associated fracture of the femoral neck These injuries occurring together result from force or forces sufficient to cause first the dislocation and then further to break the bone (figs 1530/VIII and 1557)

Treatment of Dislocation of the Hip with Associated Fracture of the Femoral Neck In our first case, admitted 10 days after the injury, Ehalt exposed the joint through a lateral approach using a curved incision and chiselling off the tip of the great trochanter He returned the completely detached femoral head into the acetabulum and fixed the femoral neck with a Smith-Petersen three-flanged nail (figs. 1558, 1559) Since flexion, adduction and external rotation contractures developed four weeks later, we then corrected



1557, August, 4, 1935



1558, August 7, 1935



1559, August 29, 1935



1560, January 24, 1936



1561, July 23, 1936

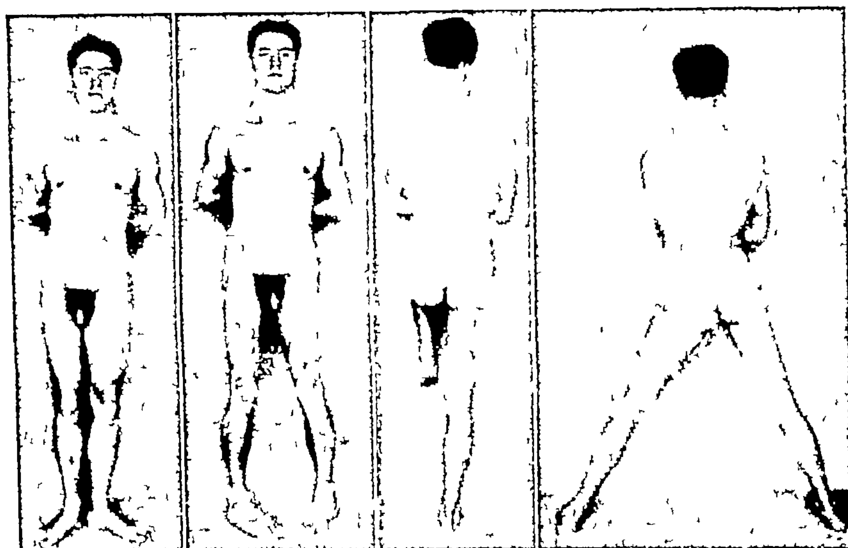


1562, October 5, 1937



1563, July 13, 1951

those deformities and applied a thoracopelvic hip spica for six months The patient got up in the cast after 26 days When the cast was removed the fracture had not yet healed and a depression of the necrotic head could be



1564, October 5, 1937

FIG 1557—Luxatio iliaca with fracture of the femoral neck sustained by a 25 year old man who fell from a cliff 40 M high

FIG 1558—Check roentgenogram re figure 1557 The hip joint has been exposed through a big curved incision and by chiselling off the tip of the greater trochanter The completely detached head has been replaced in the acetabulum and has been fixed in a position of slight valgus by means of a three-flanged nail The osteotomized greater trochanter is displaced cranially

FIG 1559—Check roentgenogram re figure 1558, three weeks later The greater trochanter has been fixed with three nails The valgus position has increased The femoral head is subluxated laterally Beginning myositis ossificans cranial to the femoral neck A plaster cast was applied at this time and left for six months

FIG 1560—Check roentgenogram re figure 1558, six months later Bony union in the lateral part, crushing in the upper part of the femoral head Myositis ossificans has increased A broad bony spur extends from behind the femoral neck towards the inferior lip of the acetabulum Range of motion about 10° in all directions A severe adduction contracture developed about a fortnight after removal of plaster It was corrected under general anaesthesia and another cast was applied and left for another six months

FIG 1561—Check roentgenogram re figure 1558, one year later Firm bony union of fragments Proximal epiphysis has disappeared Hip joint is stiff Walking even long distances is painless

FIG 1562—Lateral check roentgenogram re figure 1558, 26 months later The bony spur caused by the myositis ossificans of the short rotators (quadratus femoris et gemelli) is well seen Bony union of fragments Femoral head has disappeared

FIG 1563—Check roentgenogram re figure 1558, 16 years later Bony ankylosis of hip joint in good position Broad bony spur below the femoral neck from the pelvis to the thigh caused by ossification of gemelli and quadratus femoris Fully capable of bearing weight and walking long distances without pain and without limp

FIG 1564—Photographs re figure 1562, 26 months after the accident Hip stiff with the limb in good position The apparently good rotation mobility is not real it is the result of simultaneous rotation of the pelvis and limb Standing on the injured leg does not cause pain Abduction is accomplished entirely in the sound hip Patient works in a factory all day long and has no pain whatsoever Has already been skiing

seen in the roentgenogram (fig. 1560) Bony union occurred one year later (fig 1561) A lateral roentgenogram made two years later showed extensive myositis ossificans along the posterior side of the femoral neck where the displaced femoral head had earlier resided for the ten days following injury. "Extra-articular ankylosis" developed with the limb in a good position so that functional and cosmetic results are good The patient is able to walk and work without pain, and he even goes skiing During the 17 years of close follow-up in this case we have noted no deterioration in his condition (fig 1563)

Removal of Fractured Femoral Head In two of the remaining three cases we removed the fractured femoral head on the day of the accident and in the third case we removed the head one month later, in each case placing the remaining stump of the femoral neck into the acetabulum Results were bad in all three cases, the involved limbs ultimately showing severe contractures, markedly reduced mobility and considerable pain

Proximal Femoral Prosthesis The best treatment is replacement of the head fragment with a proximal femoral prosthesis of acrylic, stainless steel or vitallium The operation is best done on the first or second day after the accident, provided the patient is not in shock It should not be needlessly delayed, since prolonged presence of the dislocated head displacing muscles about the hip leads to myositis ossificans with consequent diminution of mobility of the joint If the patient's general condition does not permit the entire operation to be done at once, the femoral head may be removed, traction applied, and the acrylic or metal head prosthesis inserted 3 or more weeks later If the remaining distal femoral neck fragment is very short a prosthesis with a "femoral neck" and a long associated stainless steel or vitallium medullary nail should be used

Arthrodesis of the Hip Joint On the basis of the good result in our first case with an unintentional extra-articular arthrodesis, one might think it not to be amiss to use the fractured femoral head and neck as an autograft for arthrodesis Best time for such operation is between the second and the fourth week, after the patient has fully recovered from any eventual shock During that time traction should be applied (fig 1604 a) in order to avoid shortening of the limb Operation can also be performed later In that case, as shown in figures 1560—1563, a myositis ossificans will develop and will strengthen the intra-articular arthrodesis with the extra-articular new bone as in figures 1561—1563

Operation With a posterior dislocation the joint is exposed through a posterior incision, in anterior dislocation through an anterior one Then the head is removed and is denuded of cartilage After cartilage and subchondral bone have all been removed from the acetabulum the femoral head is placed in the acetabulum and fixed temporarily in good position with two Steinmann pins The "joint space" is filled with bone chips. After provisional closure of the wound the patient is placed on the screw traction apparatus as for nailing of a femoral neck fracture (figs 1701, 1702). Through a lateral incision a guide wire is inserted into the femoral neck, crossing over into the acetabular roof as far laterally as possible If roentgenograms then show good position

of the wire, the Steinmann pins are removed and a cannulated three-flanged nail 16—17 cm long is driven in over the guide wire If it is in good position another guide wire is inserted parallel to it, and another three-flanged nail is driven over that wire as in figure 1565 f The entire operation is done as is that for nailing of a femoral neck fracture (see page 1239) The limb is placed on a pillow in bed, and then four weeks later the patient will be able to walk

TREATMENT OF DISLOCATION OF THE HIP WITH ASSOCIATED FRACTURE OF THE FEMORAL SHAFT (Group IX, Figure 1530/IX)

We have not yet seen any recent closed dislocation of the hip with associated fracture of the femoral shaft We have, however, seen a recent *open* anterior dislocation with concomitant ipsilateral open fracture of the femoral shaft That patient died after enucleation of the head of the femur During the war I received two patients who had been run down by a car and had each suffered transverse fracture of both femoral shafts and superoposterior dislocation of the left hip Since the cases were more than two months old when I received them, the femoral fractures were treated with intramedullary nails and then the hip dislocations were reduced by open operation and arthrodesis was performed (M N [1]/figs 307—316) Since that time three somewhat similar cases have been reported to me in which the dislocation of the hip had not been recognized, the symptoms of fracture of the femoral shaft being always more conspicuous If one would adopt the rule calling for inclusion of both adjacent joints in all roentgenograms of bone for fractures, concomitant ipsilateral dislocation of the hip would be overlooked less frequently in the presence of dominating fracture of the femoral shaft Dehne and Immermann [2] have described 42 cases of this sort

Suggested Closed Reduction We suggested in 1938 the reduction of recent dislocation of the hip with associated fracture of the femoral shaft just as in isolated dislocation of the hip (fig 1533) It is perhaps possible in such a case to place the femoral head into the acetabulum as we know to be possible of the shoulder with associated fracture of the humeral shaft (Vol I [3]/figs 733, 734)

Reduction with Wire Traction on the Proximal Fragment We suggested further that, if the above method should fail, one might drill a wire transversely through the distal end of the proximal fragment and apply a tension stirrup through which traction could be exerted as in the "standard" reduction (fig 1533) Since publication of these suggestions I have both heard and read that such attempts have been successful Hauke [4] published such a case in 1944

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[1] M N = *Medullary Nailing of Kuntscher* by Lorenz Bohler, translated by Hans Tretter, Baltimore, Williams & Wilkins, 1948

[2] Dehne and Immermann Dislocation of the Hip Combined with Fracture of the Shaft of the Femur on the Same Side, J Bone & Joint Surg *33 A* 730, 1951

[3] Bohler, L The Treatment of Fractures 5th Edition (in English) New York, Grune & Stratton, 1956, p 606

[4] Hauke Huftverrenkung und Oberschenkelbruch derselben Seite Monatsschr Unfallh *50* 410, 1944

Open Reduction with Wire Traction Through the Proximal Fragment and with Subsequent Intramedullary Nailing. If there is no shock the fracture ends of the femoral shaft fragments can be exposed and a wire drilled through the proximal fragment Then the dislocation of the hip can be reduced by traction After having removed the wire, one can then do open medullary nailing of the fracture of the femoral shaft as described in M N /pp 187—196

In dislocation of the hip with associated fracture of a big superoposterior bone wedge from the acetabular roof, the wedge can be reduced and secured with a screw after medullary nailing of the fractured femoral shaft if the patient's general condition is good

Subsequent treatment is the same as in simple dislocation of the hip (see page 1093)

CAUSE, PREVENTION AND TREATMENT OF EARLY COMPLICATIONS FOLLOWING DISLOCATION OF THE HIP

Early complications following dislocation of the hip are· 1 Death, 2 Need for disarticulation and amputation; 3 Disturbed blood supply, and 4 Nerve lesions

Cause and Prevention of Death Of our 79 cases of dislocation of the hip, ten have died within a few hours because of severe concomitant injuries (serial costal fractures, comminuted fractures of the pelvis; rupture of the urethra, kidney and spleen, and fat embolism) Four have died between the 37th and 167th days: the first in an attack of cardiac asthma on the 37th day, the second of pyelonephritis resulting from a simultaneceus vertebral fracture with paraplegia on the 167th day, the third with a metapneumonic empyema on the 82nd day, and the fourth of septicemia after operative reduction of a dislocation of the hip because of interposition of a fragment in the hip joint on the 104th day (this was in 1940 under wartime conditions).

Among the 14 fatal cases, death as a direct consequence of hip dislocation occurred in only the last of the above four cases It could probably not have been avoided in the other cases It is all-important to treat shock adequately before reducing the dislocation

Cause and Prevention of Disarticulation and Amputation One patient had sustained a deep laceration entering the right hip joint with dislocation of that hip and concomitant ipsilateral open fracture of the femoral shaft as well as other severe concomitant injuries He died six hours after the limb had been disarticulated at the hip In another case there developed a gangrene of the lower leg, probably because of arterial embolism A Callander amputation was done on the eleventh day

The complications in these two cases could not have been avoided.

Origin, Prevention and Treatment of Circulatory Disturbances Amongst our cases of closed dislocation of the hip we have seen circulatory and sensory disturbances in only one case, that being an anterolateral dislocation As long as the femoral vessels and the femoral nerve were displaced laterally by the dislocated femoral head with the hip in full extension, the leg was pale and mottled and there was no palpable pulse in the foot As soon as the hip

was flexed, however, the circulation and color of the skin became normal and the pulse in the foot became palpable

In an anterior dislocation of the hip described by Goeringer,[1] pressure of the femoral head caused a thrombosis of the femoral vein within five hours Embolism occurred during reduction Death occurred after three minutes

These disturbances of blood supply and their consequences can be avoided if the hip is flexed to a right angle as soon as the circulatory disturbances are discovered and if the dislocation is then reduced as soon as shock has been adequately treated

Origin, Prevention and Treatment of Nerve Lesions Nerve lesions in association with hip dislocation occur either in the accident or during reduction because of overstretching of the nerve and because of the pressure on it of the femoral head or of a fracture fragment This nerve damage during reduction is noted especially in old cases in which reduction is performed not gently but with considerable force We have never seen them occur during reduction in any of our cases According to published reports of operations done because of such nerve damage, the nerve has never been found severed If reduction is performed gently on the first day after injury, the paralysis will disappear spontaneously in more than half of the cases Seven of our 79 cases of dislocation of the hip showed nerve lesions, viz, 6 cases (7 6%) with changes in the distribution of the sciatic nerve with posterior dislocations, and one case (1 3%) with changes in the distribution of the femoral nerve with an anterolateral dislocation To my knowledge, no other cases of femoral nerve lesion with hip dislocation have ever been reported In our case the lesion disappeared immediately after reduction. Of the six cases of paralysis with posterior dislocation, in four the sciatic nerve was affected and in two the peroneal nerve In three of the cases of sciatic nerve paralysis, the paralysis disappeared after a few days, whereas in the fourth, as well as in the two cases of paralysis of the peroneal nerve, the paralysis was permanent In the three cases of permanent paralysis the dislocations were reduced after from three to eight days, while in the four cases of transient paralysis they were reduced on the day of the accident itself It should be pointed out that in our cases paralysis occurred only after posterior *fracture-dislocations*, and never after pure posterior dislocations Most authors who have seen relatively large numbers of cases report that 7 to 12 per cent of their cases have shown paralysis and that permanent paralysis has occurred mostly in cases in which delayed reduction has been done

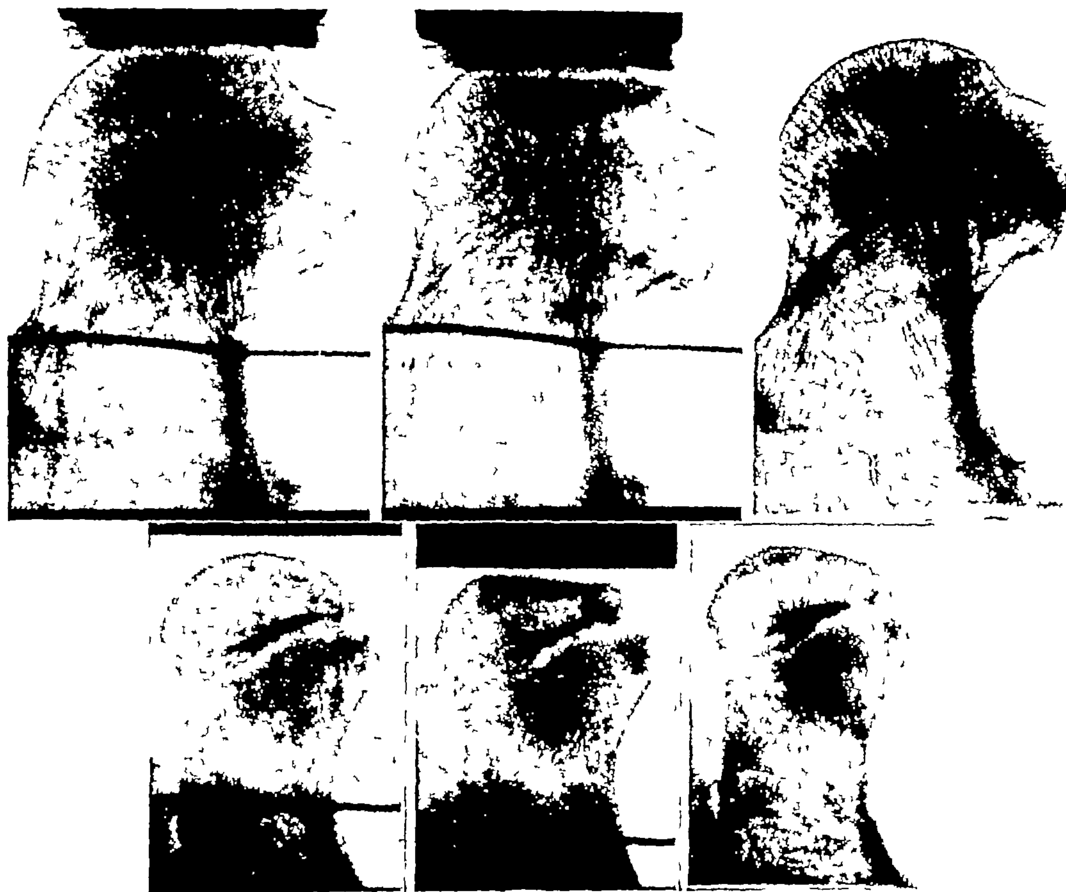
Permanent paralysis with contractures of the foot, mainly pes equinovarus, and with trophic ulcers belongs among the most disagreeable complications after dislocations of the hip

Permanent paralysis is best prevented by early and gentle reduction on the very first day in order to relieve the nerve from pressure as soon as possible

Operative Treatment of Paralysis If in dislocations of group IV there is a big superoposterior fragment which cannot be reduced, it should be openly reduced and secured with a screw Marginal fragments from the head (group VI)

[1] Goeringer, C F A danger signal in traumatic anterior dislocation of the hip Am J Surg *74* 833, 1947

or fragments from the femoral neck (group VIII) should be removed if they lie posterior to the joint near the sciatic nerve As a rule these operations are successful only if they are performed on the day of the accident. If paralysis occurs in a pure dislocation, operation is superfluous, since previous experience has shown that the nerve is not severed in any of these cases



1564 a—f Femoral head compression tests done by Jorg Bohler [1]

Fig 1564 a, top left—Strong femoral head and neck taken from the body of a 60 year old man shortly after death and put in an apparatus for testing solidity, without pressure

Fig 1564 b, top middle—Under pressure of 1070 Kg the surface of the head became depressed, and later the neck became impacted into the head Thus a fracture in the cartilage-bone border region resulted

Fig 1564 c, top right—Pressure diminished Except for a small spot on the cortical bone, the depressed area is no longer visible Evidence of impaction in the cartilage-bone border region has disappeared with essentially complete restoration of the former contours

Fig 1564 d, bottom left—Femoral head and neck taken from the body of an 8 year old boy shortly after death, without pressure

Fig 1564 e, bottom middle—Under pressure of 360 Kg there is considerable flattening of the head with increased density of the cancellous framework

Fig 1564 f, bottom right—Pressure has been removed Almost complete restoration of the head to its former shape and size

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[1] Bohler, Jorg Experimentelle Untersuchungen uber die Ursache der sogenannten Kopfnekrose nach Verrenkungen und Verrenkungsbruchen des Huftgelenkes Der Chirurg 24 344—349, 1953

If deformities of the foot develop they should be corrected in order that walking not be severely impeded

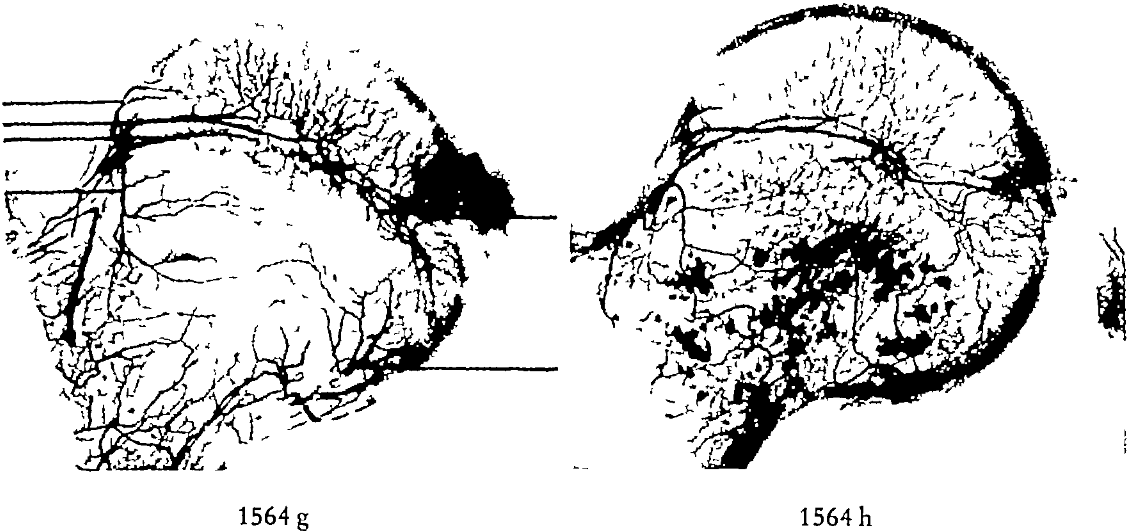
Amputation in Paralysis. If trophic ulcers do not heal, and cause pain for months and years, amputation should be considered

ORIGIN, PREVENTION AND TREATMENT OF LATE COMPLICATIONS AFTER DISLOCATION OF THE HIP

Late complications after dislocations of the hip are· (1) Myositis ossificans, (2) Necrosis of the femoral head, (3) Arthrotic changes; and (4) Pain and limited movement

Origin, Prevention and Treatment of Myositis Ossificans [1]

The development of myositis ossificans has been discussed in Vol I/pp. 60 through 76 It results from delayed or repeated, forcible reduction maneuvers as well as from vigorous subsequent treatment with massage and passive motion



1564 g 1564 h

FIG 1564 g and h—Angiograms of the femoral head and neck after Trueta and Harrison [2]
FIG 1564 g—Angiogram after injection of barium into femoral head vessels of a 20 year old man The blood supply of the proximal epiphysis derives mainly from vessels of the capsular coat entering at the lateral side of the epiphyseal region Besides, prominent vessels entering through the ligamentum teres are seen

FIG 1564 h—Angiogram after similar injection of barium in a 70 year old man Here, too, the blood supply of the proximal epiphyseal region derives mainly from vessels entering at the epiphyseal line Besides, vessels entering through the ligamentum teres are still to be seen

Among our 65 surviving cases of dislocation of the hip, reduction was done on the first day in 47 cases In these 47 cases, no myositis ossificans developed Six cases were reduced on the 2nd or 3rd day, and myositis ossificans developed in one of these Among the seven cases in which reduction

[1] Trojan, E Die Myositis ossificans nach traumatischen Huftverrenkungen und Huftverrenkungsbruchen Archivio Putti, 1953

[2] Trueta, J and Harrison, M H M The Journal of Bone and Joint Surgery, *35 B* 442—461, 1953

was done from the 4th to the 20th day, myositis ossificans developed in three And it has developed in two of our cases of dislocation with associated fracture of the femoral neck following removal of the head fragment

Myositis ossificans may be recognizable in the roentgenogram as early as the end of the third week If subsequent treatment does not include either vigorous passive motion or massage, it will not increase to any considerable degree after that time (figs 1536 and 1559—1663). It is particularly marked in cases of old, long-unreduced cases of dislocation in adults (figs. 1537—1540), while it as a rule does not develop in children and adolescents (figs 1541 through 1546).

This all indicates again that myositis ossificans is not the result of the trauma of the dislocation but rather that it develops only in cases in which reduction is delayed and in those in which, after early and careful reduction, massage and passive motion are used (see Vol I/p 63)

In spite of the usually marked tearing of muscles in these cases, our experience indicates that it is not necessary to apply a plaster cast for prolonged immobilization of the joint in order to avoid myositis ossificans.

Operative removal of the calcified muscles, as has been done with good results in the region of the elbow (see Vol I/figs 61—68), offers no promise of success in cases of dislocation of the hip

Origin, Prevention and Treatment of Necrosis of the Femoral Head Following Dislocation of the Hip

Necrosis of the femoral head, with its pain and contractures and interference with the patient's ability to walk, belongs together with permanent paralysis among the most undesirable complications following dislocation of the hip Some authors state that it occurs in 20—30 per cent of all such cases Among 58 of our cases which have been followed for two years or longer, necrosis of the head of the femur has developed in seven (12 1%)

Cause of Femoral Head Necrosis It develops either as a result of primary damage to the femoral head at the time of the accident or secondarily because of rupture or obstruction of the nutrient vessels

Direct Damage to the Femoral Head In the fracture-dislocation of Group IV resulting from shearing force, the acetabular roof strikes the fixed femoral head so violently that part of the roof is sheared off by the head (figs 1930/IV and 1546 c) Jorg Bohler's experimental work [1] has shown that the femoral head is more or less depressed and flattened by this force but that it springs back to essentially its original shape as soon as the force upon it ceases (figs. 1564 a—f). Flattening of the head is, of course, possible only with collapse of the trabeculae in the cranial side of the head — the flattened side, that is The fact that the resilience of the head causes it to spring back into essentially its normal shape immediately after cessation of the flattening force explains why the usual roentgenograms fail to show abnormality of the

[1] Bohler, Jorg Experimentelle Untersuchungen uber die Ursache der sogenannten Kopfnekrose nach Verrenkungen und Verrenkungsbruchen des Huftgelenkes Der Chirurg 24 344, 1953

pongiosa either before or after reduction Perhaps improved roentgen techiques will yield films of such quality that appropriate enlargement of them vill allow much more exact study of trabecular structure, or perhaps precise omography may allow recognition of changes there Jorg Bohler had 29 femoral heads from fresh cadavers put under varied pressures in a technical experimental laboratory He then studied the structure of those heads and found that pressures of from 300 to 1000 Kg caused flattening which disappeared immediately after pressure was removed The cartilaginous coat often became fissured Roentgenograms during the compression clearly show the collapsed spongiosa trabeculae (figs 1564 a—f)

Baumann [1] made similar experiments with lumbar vertebrae They were compressed to wedges and still regained essentially their old shape after pressure had ceased Roentgenograms of those specimens did not show any recognized sign of fracture

Direct damage to the femoral head occurs in dislocations of the hip with shearing off of the superoposterior part of the acetabular roof (group IV) and in dislocations in which a marginal fragment is fractured from the femoral head (group VI) The femoral head is also compressed in central dislocations of group I (see page 1131), which frequently leads to femoral head necrosis

In order to see at autopsy the fissures in the articular cartilaginous coat, the crushing of the trabeculae in the spongiosa and the accompanying hemorrhages in fracture-dislocations caused by thrust and shearing forces, and in order to see the probably sound femoral heads in pure dislocations, the involved joint should be exposed in all fatal cases, both recent and old, and longitudinal sections of the femoral head should be made in order that one may check on the correctness of these findings and the assumptions involved in their clinical application Up to now we have unfortunately failed to do this, although we have had the opportunity in 14 cases (see page 1128) In five of these 14 cases we did dissect the joint in order to examine the soft tissue injuries

Indirect Damage to the Femoral Head by Rupture or Obstruction of its Nutrient Vessels In order to understand necrosis of the femoral head resulting indirectly from rupture or obstruction of the nutrient vessels one must know the nature and location of such nutrient vessels (figs. 1564 g, h) (1) Vessels in the cranial part of the capsule, these being the largest of all, (2) Vessels entering the head through the neck, and (3) Vessels of the ligamentum teres, which are large in children, becoming less so with advancing years

In dislocation of the hip the vessels of the ligamentum teres are ruptured whereas the vessels of the femoral neck remain sound Those of the capsular coat mostly remain sound, too This explains our having seen only one necrosis with collapse of the femoral head in our 52 cases of dislocation of the hip caused by leverage (groups I and II)

In fractures of the femoral neck, however, the ligamentum teres with its vessels always remains sound The vessels of the femoral neck are invariably

[1] Baumann Zur Pathogenese der degenerativen Wirbelsaulenerkrankungen Helvetica chirurgica Acta, Series B, Vol 17, Fasc 4/5, S 345—353, 1950

ruptured when there is considerable displacement, the extent of rupture of those in the capsular coat is dependent upon the extent of the displacement

In impacted abduction or valgus fractures of the femoral neck, necrosis of the femoral head develops in 10 to 15 per cent of all cases because the vessels in the cranial part of the femoral neck are compressed and obstructed

In adduction or varus fractures of the femoral neck there may be rupture of only a few of the vessels of the capsular coat or there may be rupture of all of them, depending upon the degree of displacement All of the femoral neck vessels are ruptured This leads to more or less considerable disturbance of nutrition with calcification and development of cysts or to necrosis of the entire head

In dislocation with fracture of the femoral neck, from group VIII (figs 1530/VIII and 1557), all vessels are torn If the femoral head is not removed in such a case, necrosis and collapse of the femoral head will develop (figs 1559—1563).

Necrosis of the Femoral Head Following Dislocation of the Hip in Children In the child the femoral head is nourished mainly by way of the vessels of the ligamentum teres As the ligamentum teres is usually, though not always, torn in dislocation of the hip in children, necrosis of the femoral head following pure dislocation of the hip occurs more frequently in children than in adults where the femoral head is nourished primarily through the vessels of the capsule and the femoral neck As necrosis develops there comes a dragging pain, and the femoral head becomes dense in the roentgenogram It collapses a few months later with resulting coxa plana with fragmentation of the epiphysis and subsequent broadening as in Perthes-Legg-Calvé's disease One sees the same picture after fracture of the femoral neck in children (figs 1886—1891)

Necrosis of the Femoral Head Caused by Massage and Passive Motion. Authors like Magnus and Wette, who advocate and broadly apply massage and vigorous passive motion report an extremely large percentage of their cases to develop necrosis of the femoral head These two extremely popular modalities tend to disturb the process of healing of the lacerations in capsule and muscles Irritation of the afferent nerves causes pain and the pain causes again irritation of the efferent vasomotor nerves, at first with constriction and later on with dilatation of the capillaries The result is passive hyperemia This is the cause of decalcification of bones, of swelling of soft tissues and of subsequent contraction of capsule, ligaments and muscles If this irritation is continued the bone will become more and more deficient in calcium and more and more liable to collapse Similar changes with demineralization and structural alteration in the bone are also seen resulting from continued passive motion following dislocation of the shoulder (Vol I/fig 48) Our experience indicates that immobilization in plaster after dislocation of the hip is not necessary

Necrosis of the Femoral Head with Crushing by Early Weight Bearing Most reports of femoral head necrosis following dislocation of the hip do not distinguish between those cases in which there was pure dislocation caused by leverage and those cases in which there was fracture-dislocation caused by

thrust and shearing force There is a fundamental difference between these two kinds of dislocation: in the first category the femoral head leaves the acetabulum without having been subjected to any considerable contact pressure, whereas in the second category the head is invariably more or less contused, especially in groups IV to VI (figs 1530/IV—VI), when the acetabular roof suddenly strikes against the femoral head and is sheared off by it (as in car collisions) as described on page 1075

Among our 60 cases of dislocation of the hip in Groups I—III (figs 1530/I—III) we have seen only a single case of necrosis of the femoral head with crushing, although most of the patients got up and started weight-bearing as early as the first week after injury The only patient in whom a necrosis of the femoral head developed had stayed in bed for ten weeks because of his having sustained a concomitant contralateral open fracture of the femur However, since severe arthrotic changes of the contralateral hip developed in addition, his case may have been one of systemic disease (figs 1534, 1535) One might also consider the possibility that arthrotic changes in one hip joint might lead to sympathetic arthrosis in the other hip joint, as is the case with sympathetic ophthalmia The youth (seventeen years) of this particular patient might also have played a rôle here

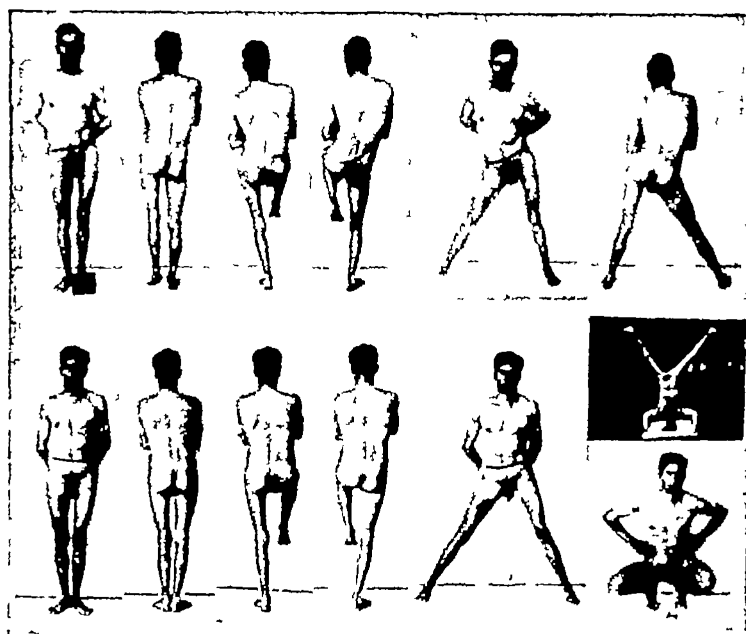
In fracture-dislocations of groups IV—VI (figs 1530/IV—VI), weight-bearing on the involved femoral head should be avoided for three to four months

Influence of Delayed Reduction on the Development of Necrosis of the Femoral Head Six of our seven cases of necrosis with collapse of the femoral head have been reduced between the 2nd and the 13th days Thus it seems that the time at which reduction is done has much to do with the development of necrosis This opinion is shared by many authors The femoral head, having collapsed during the accident and having been entirely free to assume its former shape after reduction on the first day, will generally not collapse again later if pressure upon it is avoided by continuous traction for three or four months If, however, the dislocation is not recognized at once and therefore not reduced at once, the nutrient vessels will be obstructed partly because of stretching and partly because of direct pressure If the obstruction continues beyond a certain time, the vessels may thrombose Thus the blood supply to the fractured region of the femoral head will be impeded or cut off, and the head will collapse with weight-bearing later on If, however, adequate circulation resumes because of early gentle reduction on the first day, and if the fractured femoral head does not too soon thereafter bear any weight, the fractured trabeculae of the spongiosa will undergo bony union within three or four months and usually will not collapse again later on

Time of Development of Necrosis of the Femoral Head with Depression The first change in density of the femoral head can sometimes be observed as early as six weeks after the injury The earliest depression we have seen occurred after three and a half months In one case (figs 1534, 1535) the depression was discovered only four and a half years after the accident, since no roentgenograms had been made in the meantime The patient, however, had suffered from pain and limited movement two years after the accident



1565 a, April 18, 1950 1565 b, June 6, 1950



1565 c, June 6, 1950

Fig 1565 a —Necrosis of the femoral head with depression five years after dislocation of the hip in a 34 year old rural laborer who fell into a river with his horse-cart Reduction done on the third day Considerable adduction and external rotation The cranial part of the head is missing The caudal part of the head and the femoral neck are dense Joint "space" not visible

Fig 1565 —Check roentgenogram re figure 1565 a, six weeks after arthroplasty of the hip with an acrylic head The femoral head is of course missing The radiolucent acrylic head lies in the acetabulum Now the limb can be adducted

Fig 1565 c, top —Photographs re figure 1565 a Adduction and external rotation of the left lower limb Apparent shortening of that limb leg by 6 cm is due to adduction contracture The left lower limb is much weaker than the right one When the patient stands on the left leg the right half of the pelvis drops down (positive Trendelenburg sign) Adduction contracture is especially striking when the patient attempts to abduct both lower limbs The patient limps and has pain

Fig 1565 c, bottom - Photographs re figure 1565 b, six weeks after arthroplasty of the hip The lower limbs appear to be of equal length Trendelenburg sign has almost disappeared Abduction 50°, In head-stand, i e, without weight bearing, abduction seems to be free Deep knee-bending possible No limping, no pain

Therefore changes must have been present at least as early as that Cases have been reported in which changes were thought to have developed five years after injury It seems they do not occur after that time

Apart from the cases with depression of a necrotic femoral head there are cases of trophic disturbances with dense foci and cysts within the head but without depression Such cases are sometimes asymptomatic Arthrotic changes, however, may develop as late as eight years after the accident

Prevention of Necrosis of the Femoral Head with Depression Following Dislocation of the Hip According to our experience and that of many other



1565 d, January 28, 1951 1565 e, February 10, 1953

Fig 1565 d—Necrosis and depression of femoral head in a 52 year old man, seven years after a fracture-dislocation of the left hip which had been reduced twice under anesthesia and immobilized in a plaster cast for three months Caused by a fall during military drill No adduction contracture, only slight contracture in external rotation Dense foci and cysts in femoral head and acetabular roof A large bone wedge seems to have been fractured from the acetabular roof Large marginal exostoses on the acetabular roof and the femoral head Joint space is barely visible and is irregular No motion in the hip Walking painful and requires a stick

Fig 1565 e—Check roentgenogram re figure 1565 d, two years after arthrodesis with two long three-flanged nails The joint region was comminuted with the chisel from the lateral side Bony ankylosis Patient has been walking long distances without cane and without pain

authors, necrosis of the femoral head develops especially in cases of dislocation of the hip in which reduction has been delayed Therefore a dislocation should be recognized on the first day and then immediately and gently reduced Especially in fracture-dislocations of group IV (figs 1530/IV and 1532 b) the dislocation is frequently not recognized, since the typical defor-

mity with "springy fixation" is sometimes lacking and the roentgenogram is often incorrectly interpreted Fracture-dislocations of group IV are especially subject to complications Crushing of the femoral head can generally be avoided if the fracture-dislocation is recognized on the first day, reduced gently and immediately, and if the limb is then kept in continuous traction (fig 1604 a) with a joint diastasis of five to six mm for three or four months

Massage and forcible passive motion must never be used in the mistaken believe that one might thereby increase joint mobility when that mobility is limited by pain

Early weight bearing does not cause necrosis of the femoral head in dislocations in groups I to III (figs 1530/I—III)

If in children the femoral head becomes dense and shows depression, the collapse can be avoided if such children are treated with continuous traction or with a short weight-bearing plaster spica (figs 1678, 1679) or with a weight-bearing caliper until roentgenograms show the femoral head to have a normal calcium content. For continuous traction a foot sling with two kilos will sometimes be sufficient If a short weight-bearing plaster cast is applied it must be checked at least every four weeks to make sure that no weight whatsoever is borne by the femoral head

Treatment of Depression of the Femoral Head following Dislocation of the Hip In children, collapse of the femoral head can be avoided if the femoral head does not bear any weight for two or three years after the dislocation Sometimes the head will regain its old shape

It is useless to avoid weight bearing in adults with collapsed femoral head If contractures supervene with pain and limited motion, an arthrodesis (fig 1565 e) or an arthroplasty (fig 1565 b) may be performed

Etiology, Prevention and Treatment of Arthrotic Changes Following Dislocation of the Hip

Etiology Dislocations of the hip with subsequent necrosis and depression of the femoral head always ultimately show severe arthrotic changes Such changes are comparatively rare following other dislocations of the hip We have seen them develop only once amongst the 34 surviving patients with pure dislocation of the hip, and those were only slight changes probably due to disturbances of the blood supply They developed, however, in seven out of 31 survivors with fracture-dislocation Two of those seven patients were asymptomatic In most of the other cases the femoral head had been injured in the accident (groups IV, VI, and VIII) At first, still in the absence of recognized roentgenographic change, slight pain and somewhat limited motion, especially rotation, supervene Later dense foci and cysts of various size develop, and then months or years later the joint "space" may become narrowed because of atrophy and thinning of the articular cartilage, and marginal exostoses will appear on the femoral head and the acetabulum In order to show best the marginal exostoses on the femoral head, an anteroposterior roentgenogram of the whole pelvis with the patient in the lithotomy position should be made (fig 1535) This will show the marginal exostoses

or osteophytes to be clearly projected in profile, whereas they tend to be superimposed upon acetabular osteophytes in ordinary anteroposterior roentgenograms of advanced cases

In contrast to arthrosis developing after femoral neck fracture, which generally appears as late as four to eight years afterward, that following dislocation of the hip sometimes appears as early as one year after the accident.

Prevention Authors advocating forcible massage and passive motion report a relatively high percentage of arthrotic changes Massage and passive motion should be avoided

Treatment consists in avoiding over-exertion and in baking, sessions of the latter never exceeding ten minutes If pain is severe and persistent, athrodesis or arthroplasty should be considered

Cause, Prevention and Treatment of Pain and Limited Movement

In cases showing no roentgenographic changes, pain and limited movement generally do not occur They are primarily sequelae of arthrotic changes developing on the basis of injuries to the femoral head during the accident Incidentally, pain and limitation of motion do not always develop simultaneously or progress equally

Treatment Most surgeons seem to consider passive motion and massage the best methods of treating limited joint motion Actually these measures always make the condition worse The most successful treatment consists in gentleness and the use of warmth If motion diminishes and the joint becomes stiff, pain decreases and may even cease altogether If pain increases and persists, arthrodesis or arthroplasty may be considered

Results in 79 Cases of Dislocation of the Hip

Formerly, results were generally considered good Follow-up examinations by Magnus (1927), Wette (1929), Blumensaat (1936), Heizmann (1936), Obwegeser (1936), Funsten (1938), Pfab (1938), Roth (1940), King and Richards (1941), Urist (1947), Armstrong (1948), Paus (1951), Thompson and Epstein (1951), and Trojan and Perschl (1954) found severe permanent disability in a large number of cases Magnus and Wette found considerable abnormalities in the roentgenograms of 47 out of 57 cases (82 5%), viz, calcification of muscles and ligaments, or necrosis of the femoral head and arthrotic changes The results of Heizmann's examinations were much the same

In order to ascertain the influences of the kind of accident, type of dislocation, age of the patient, method and time of reduction, and method of postreduction treatment on the end-result, I asked Obwegeser[1] to do follow-up examinations on the ten cases of dislocation of the hip I had reduced from 1929 to 1934 He later published without exception all prereduction roentgenograms and those made for the follow-up examination

In 1942, Scheel[2] did follow-up examinations on the 25 cases of dislocation of the hip I had treated in the years 1929 to 1939

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[1] Obwegeser Symptome, Behandlung und Prognose frischer traumatischer Huftverrenkungen Arch Orthop und Unfall-Chir *37* 80—106, 1936

[2] Scheel Dissertation, 1942

Trojan and Perschl[1] reviewed the 79 cases of dislocation of the hip we had treated from 1929—1949, viz., 43 pure dislocations and 36 fracture-dislocations Obwegeser's and Scheel's cases were examined again when and if possible I reviewed with my assistants every series of these 79 cases four times between 1950 and 1952, as well as the earlier ones with Obwegeser and Scheel, in order to find out the cause of disturbances following dislocation of the hip as well as to find means for preventing such disturbances

Fatal Cases Of our total number of 79 patients, ten died of severe concomitant injuries during the first hours after the accident and four died between the 37th and the 167th days, viz, one of infection following operation and the remaining three of unrelated diseases (coronary occlusion, metapneumonic empyema, paraplegia)

Disarticulation In a patient with open dislocation of the hip and simultaneous ipsilateral open fracture of the femur and other severe concomitant injuries, the limb was disarticulated at the hip He died six hours after the accident

Amputation In one case, gangrene of the lower leg developed The patient's limb had to be amputated proximal to the knee on the eleventh day

Reduction has been tried in 60 cases in the manner shown in figure 1533 and has been successful in 57 cases

Immobilization Of the 43 patients with pure dislocation of the hip (see page 1080), 24 that had not sustained any concomitant injuries to the lower limbs got up between the 2nd and the 25th days, i e, after an average of nine days Of 15 stable fracture-dislocations of the hip in groups II and III, six having no concomitant injuries to the lower limbs got up between the 8th and the 15th days, i e., after an average of eleven days

Summary. Of the cases of pure dislocation of the hip and in the stable cases of groups II and III, 30 without concomitant injuries to the lower limbs were able to get up between the 2nd and the 25th days, i e, after ten days on the average Of the unstable cases in groups IV to IX, some were treated with continuous traction, some operatively

Period of Observation Clinical findings and roentgenograms are available for the 65 remaining patients who survived

2 cases were observed for more than 20 years,
8 (2 + 6) cases were observed for more than 15 years,
27 (8 + 19) cases were observed for more than 10 years,
48 (27 + 21) cases were observed for more than 5 years, and
61 (48 + 13) cases were observed for more than 2 years

As 48 cases (73 8%) were observed for more than five years, and as our experience has shown that necrosis of the head and severe arthrotic changes do not supervene after that time, we think ourselves justified in drawing rather certain conclusions concerning late complications

Paralysis developed in seven (8.9%) of our 79 cases of hip dislocation, viz, one case of very transient paralysis with a pure anterior lateral dislocation

[1] Trojan L, and Perschl 'Behandlungsergebnisse von 79 frischen traumatischen Hüftgelenksverrenkungen (H V) und Hüftgelenksverrenkungsbrüchen (H V B)" Ergebnisse der Chirurgie u Orthopädie, 1954

and six cases of paralyis among 33 posterior fracture-dislocations In four cases the sciatic nerve was affected, in two the peroneal nerve Of these six cases of paralysis, three disappeared So there were only three cases of permanent paralysis, viz., one of the sciatic nerve and two of the peroneal nerve Of these three, two were reduced on the fourth day and one was reduced on the ninth day, whereas the four cases without permanent paralysis were all reduced on the first day

There was no paralysis in the 33 pure posterior dislocations of the hip and in the nine pure anteroinferior dislocations of the hip

Myositis ossificans We have seen myositis ossificans in six of our 65 survivors (9 2%) It followed pure posterior dislocation in one case, pure anteroinferior (fig 1536) dislocation in one case and fracture-dislocation in four (figs 1562 and 1563) Reduction was delayed in four cases, i e, it was done between the 2nd and 18th days In two cases the femoral head was removed on the 1st and 35th days respectively because of concomitant fracture of the femoral neck In the cases reduced on the first day, myositis ossificans has never developed This indicates again that myositis ossificans does not result directly from dislocation but rather from delayed reduction or from passive motion and massage Magnus and Wette, who advocate early massage and passive motion, have seen it in marked degree in many cases, just as have Pfab and Roth

Avascular necrosis of the femoral head with depression occurred in seven of our 58 cases observed for more than two years, viz, in one of 32 cases in group I (figs 1534, 1535), in four of eight cases in group IV (figs 1534, 1535), in four of eight cases in Group IV (figs 1547—1556), in one of three cases in group VI and in the single case in group VIII (figs 1561—1563) Reduction was delayed in these six cases in groups IV, VI, and VIII, i e, it was done between the 2nd and the 13th days

Here, too, as in the development of permanent paralysis and myositis ossificans, delayed reduction plays a major rôle

Nutritional disturbance of the femoral head without depression was observed in three cases, in one of which the dislocation had been reduced on the first day and in the other two of which it had been reduced on the second day

Arthrotic changes developed in all of the seven cases of necrosis of the femoral head with fragmentation (figs 1534, 1535, 1551—1556)

Functional Results

very good	moderate	poor	total
31	1	2	34
15	8	8	31
46	9	10	65

Disability Pensions 44 of the 65 survivors with dislocation of the hip had industrial accident insurance, 21 had not Of the 44 patients with insurance, 24 had pure dislocation of the hip and 20 had fracture-dislocation of the hip, 15 of the 24 patients with pure dislocation of the hip had other concomitant injuries, 9 had not Of the 15 patients with pure dislocation of the hip

without concomitant injuries, 13 (86.7%) do not draw pensions. Two draw permanent pensions, viz., a 52 year old man with genua vara and flat feet without clinical or roentgenographic changes in the hip joint draws a pension of 20 per cent, and a 62 year old man who was admitted and reduced on the 17th day after injury draws a pension of 25 per cent. He developed rather marked myositis ossificans and consequent limitation of motion.

Only two of the nine patients with pure dislocation of the hip and concomitant injuries do not draw pensions. Seven draw permanent pensions of 20 to 40 per cent, two of those because of sequelae of the dislocation, viz. one because of necrosis of the head (figs. 1534, 1535), the other because of nutritional disturbances of the femoral head without depression but with limitation of motion.

Thus 4 (16.7%) of 24 insured patients with pure dislocation of the hip draw pensions of 20 to 30 per cent because of the results of the hip injury.

Of the 20 insured patients with fracture-dislocation, 11 had concomitant injuries and nine had not. Four (36.4%) of the eleven patients without concomitant injuries do not draw pensions. Seven draw permanent pensions of from 20 to 60 per cent.

Of the nine patients with fracture-dislocation with concomitant injuries, only one does not draw a pension. Four draw permanent pensions of from 20 to 70 per cent because of results of the hip injury. The remaining four draw pensions because of results of concomitant injuries.

Thus 11 (55%) of the 20 patients with fracture-dislocation draw pensions of from 20 to 70 per cent because of results of the hip injury.

Of all 44 insured patients with simple dislocation of the hip and fracture-dislocation, 15 (34.1%) draw permanent pensions of from 20 to 70 per cent because of the hip injuries.

By way of comparison, Wette, an advocate of massage and passive motion, had 8 (40%) patients drawing permanent pensions of from 10 to 40 per cent among 20 with pure dislocation of the hip, whereas we had only 4 (16.7%) drawing permanent pensions among 24 with pure dislocation of the hip.

51. CENTRAL DISLOCATIONS OF THE HIP

Although we have already discussed central dislocation of the hip in Vol. I/pp. 510—515, in connection with fractures of the pelvis, we do so again here because follow-up examinations done with Wechselberger in our 57 cases and the study of the world literature have helped us in obtaining a new understanding. We have learned to distinguish between two groups differing fundamentally in origin, pathological-anatomic changes and clinical course. In group I (fig. 1566) the femoral head is subluxated toward the center of the pelvis in relation to the nonfractured acetabular roof, whereas in group II (fig. 1567) the femoral head is not subluxated in relation to the fractured acetabulum but is displaced with the acetabulum medially and cranially.

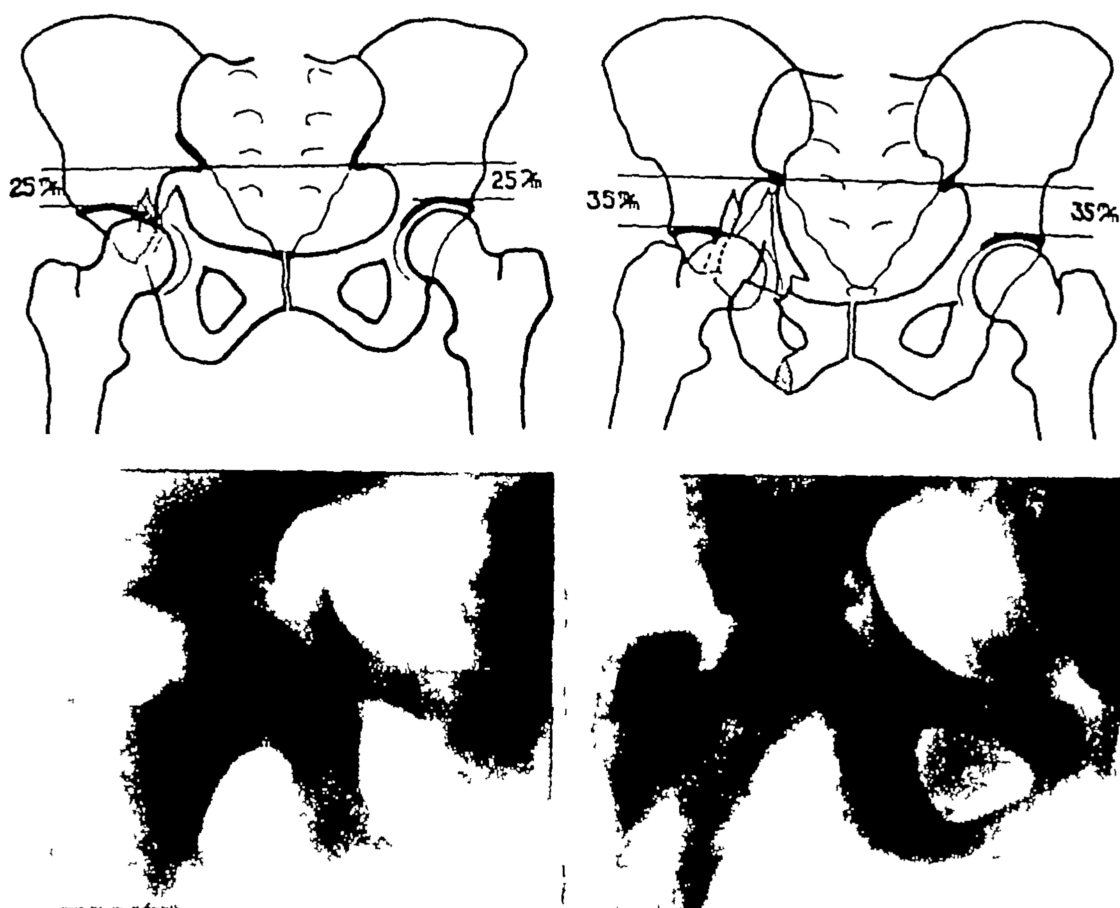
Mechanisms and Types of Fractures. It is necessary to study the skeleton of the pelvis in order to understand the different types of fractures

They result (1) from a force acting upon the greater trochanter alone (group I), or (2) from a force acting first upon the iliac crest and then on the greater trochanter (group II)

Group I Fracture of the acetabulum with central subluxation or luxation of the femoral head in relation to the nonfractured acetabular roof results from a thrust acting upon the greater trochanter in a centralward but not exactly definable direction and transmitted by the femoral neck to the femoral head The femoral head further transmits the thrust and fractures therewith the acetabulum Such fracture usually results from a fall sideways upon the prominence of the greater trochanter Thus the trochanter (and therefore, the femoral head) is brought to a sudden stop whereas the pelvis moves on It may also result from a thrust or blow against the greater trochanter, the pelvis being motionless The femoral head, receiving the force through the femoral neck, then shears off the mediocaudal part of the acetabulum and displaces towards the center of the pelvis in greater or lesser degree according to the violence of the responsible force In its pure form the fracture line runs obliquely from cranioventral to caudodorsal (figs 1566 a, 1566 c and 1567 b) It begins in the rim of the acetabulum at a point caudal to the anterior inferior iliac spine and passes dorsally and caudally to the posterior part of the iliopectineal line and the acetabulum ending at a point cranial to the ischial spine The anterocaudal part of the innominate bone, essentially that part made up of ischium and pubis, is swung as an opening door toward the center of the pelvis by the force of the femoral head, the "hinge" being the cartilaginous symphysis pubis

Usually the force is so violent as to fracture the superior ramus of the pubic bone where it joins the ilium and the inferior ramus of the pubic bone where it joins the ischium There is in addition a vertical fracture line through the fossa acetabuli The result is a Y-shaped fracture with three main fragments (fig 1567 c), the first comprising the acetabular roof and the dorsal part of the acetabulum as in pure group I, the second comprising the ventral part of the acetabulum with the ileopectineal eminence and the iliopectineal line, and the third comprising the dorsocaudal part of the acetabulum with the ischium (figs 1566 b and 1567 c and b) Often the dorsal or ventral lip of the iliopectineal line is broken off, occasionally even both of them When there is, in addition, comminution of the floor of the acetabulum, there is a confusing number of irregular fragments The superior and inferior pubic rami may also be fractured near the symphysis

Changes in the Femoral Head in Group I The femoral head is probably compressed and depressed by the force with which it is driven against the anterior part of the acetabulum, as in posterior dislocation of the hip with detachment of a large superoposterior bone wedge (figs 1530/IV, 1546 e, 1565 a). After the responsible force has ceased to act upon it, the femoral head reassumes its former contour, as Jorg Bohler (see page 1120) has shown Sometimes a permanent depression in the cranial part of the femoral head at or near the rim of the articular cartilage is caused by pressure against the sharp fracture edge in the acetabular roof (fig 1567 g) We have seen this in five of our 32 cases



1566 a—d

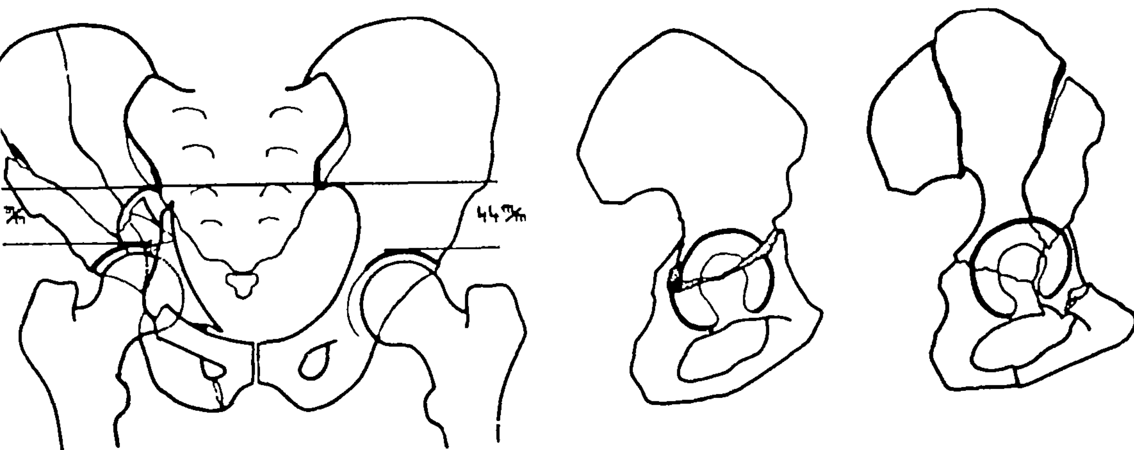
Fig 1566 a—Sketch of a pure central dislocation of the hip of Group I Acetabular roof at same level on sound and injured sides Femoral head subluxated medially relative to the uninjured acetabular roof

Fig 1566 b—Sketch of an ordinary central dislocation of the hip of Group I with comminuted fracture of the acetabulum (see figs 1567 f—h) Acetabular roof at same level on sound and injured sides Femoral head subluxated medially in relation to the acetabular roof

Fig 1566 c—Roentgenograms of a pure dislocation of the hip, Group I

Fig 1566 d—Check roentgenogram re figure 1566 c, after six hours of longitudinal traction of 12 Kg and lateral traction on the femur of the injured side with countertraction on the pelvis to the sound side, 5 Kg each Subluxation has disappeared and the fragment is well reduced Still no diastasis in the joint

Group II If the patient falls, striking first the iliac crest and then the greater trochanter, or if the iliac crest is hit by some moving object before the trochanter is hit, peculiar fracture lines will result A particularly characteristic one separates the strong anterior part of the ala ilii with the anterior superior and inferior iliac spines and the ventral part of the acetabular roof from the remainder of the ilium, and that anterior fragment is usually tilted laterally and ventrally Another fracture line may traverse the greater sciatic notch At the same time, the thrust acts upon the greater trochanter causing the same Y-shaped fracture lines as in group I Ischium and pubis are also fractured as in group I There is, however, one fundamental difference:





June 9, 1948



August 18, 1952

1567 a—e

FIG 1567 a—Sketch of a central dislocation, Group II The fractured acetabulum on the injured side lies 9 mm higher than on the sound side The femoral head is not subluxated in relation to the acetabular roof but is displaced cranially and medially with the entire acetabulum

FIG 1567 b—Sketch of lateral view of a pure central dislocation of the hip of Group I Fracture line passes from cranioventral to dorsocaudal

FIG 1567 c—Sketch of lateral view of a central dislocation of the hip, group II Y-shaped fracture lines in the acetabulum, detached anterior part of the ala ilii Another fracture line passes through the greater sciatic notch

FIG 1567 d—Roentgenogram of a central dislocation of the hip, group II Contrary to findings in figures 1566 c and 1567 f, the femoral head is not subluxated in relation to the acetabular roof

FIG 1567 e—Check roentgenogram re figure 1567 d, four years later The femoral head with the fragments of the acetabulum is pulled out from the pelvis The acetabular roof is 12 mm lower than in the first roentgenogram Normal width of joint "space" Normal nutrition of femoral head Small marginal exostosis on the lower part of the head

in group II the femoral head neither luxates nor subluxates in relation to the acetabular roof but is displaced upwards and medially together with the fractured acetabulum which has, however, undergone essentially no change of shape In group II the acetabular roof on the affected side usually lies

8—12 mm farther cranially than does the acetabular roof on the sound side (figs 1567 a, c, d), while in group I it is at the same level on the two sides (figs 1566 a—d)

Changes in the Femoral Head in Group II In group II the responsible force fractures first the ala ilii and the acetabular roof and only then acts upon the femoral head via greater trochanter and femoral neck Thus the femoral head is not depressed We have therefore found no necrosis of the femoral head among our 23 cases in group II

Combined Central Dislocations of the Hip (Group III) Amongst 57 cases of central dislocation we have found 32 cases to belong in group I and 23 cases in group II. Group I cases are more frequent because the greater trochanter projects more prominently than does the iliac crest and so is more subject to initial contact with the fracturing force Two cases showed typical fracture lines of group II and, in addition, subluxation of the femoral head in relation to the acetabular roof (group III) Such cases probably result from a force acting first upon the iliac crest and then but with still marked impact upon the greater trochanter, or in reverse order

Concomitant Injuries in the Hip Region In contrast to the situation with other types of dislocation of the hip (see page 1078), central dislocations are not accompanied by injuries to the joint capsule and ligaments and do not involve more than mild muscle damage Occasional injuries to the intestines caused by displaced and penetrating bony fragments have been reported We have not seen injuries to the ureter

Recognition of central dislocation of the hip by clinical examination is rather difficult Examination is done in the same manner as with simple dislocation of the hip (see page 1082)

Changes of shape about the hip are less characteristic than with other types of dislocation If the femoral head has sunk deep into the pelvis, a shallow depression is sometimes present in place of the usual prominence of the greater trochanter The limb is generally slightly adducted, flexed and internally rotated It frequently shows "springy fixation" Extravasation of blood and excoriations over the iliac crest or the trochanter indicate where the injuring force struck The greater trochanter is usually slightly cranial to the Roser-Nelaton line The shortening of the limb frequently cannot accurately be measured because of the pathologic position in which the limb is held

Possible Complications Following Central Dislocation of the Hip Early complications are death in shock or resulting from intestinal injury Late complications, as in pure dislocation of the hip (see pages 1082 and 1116 through 1127), are myositis ossificans, necrosis of the femoral head, arthrotic changes, pain and limitation of motion

X-Ray Examination Type and degree of injury can be recognized only in the roentgenogram The whole pelvis should be included in the roentgenogram and should be accurately aligned without any tilt or rotation The shadow of the symphysis pubis should be superimposed upon that of the center of the sacrum (see page 1083)

Questions We Should Ask Ourselves in order to Avoid Failures When Treating Central Dislocation of the Hip

We should ask ourselves the same eight questions as with other types of dislocation of the hip (see page 1088)

Treatment of Central Dislocation of the Hip

For reducing and treating a group I central dislocation of the hip one needs the same things as for treating a fracture of the femur (see page 1242), and then in addition

1 A well-padded 15 × 60 cm sling (Vol I/fig 622) for lateral traction on the thigh;
2 A well-padded 26 × 90 cm. sling (Vol. I/fig 622) for countertraction on the pelvis;
3 Six strong wire stirrups, as used with Unna's paste traction bandages (Vol I/fig 147),
4 Two pulleys for lateral traction on the thigh and the pelvis,
5 Two strong hemp cords, 50 cm. long; and
6 Two sets of 5 Kg weights (fig 1604 a)

Reduction by Continuous Traction In follow-up examinations we have noted that the best results have followed reduction by continuous traction applied properly on the first day It is applied as with fracture of the femur. A roentgenogram is made after local anesthesia of the hip joint and treatment of eventual shock Then local anesthesia is given in the distal femoral metaphyseal region and continuous traction with pin or wire is applied Preparation of the bed and other appliances, placing of the patient in the bed and of the limb on the Braun splint or on a thigh splint, application of local anesthesia, driving in of the nail, etc, are done as with fracture of the femur (see page 1249 and fig 1604 a).

Longitudinal and Lateral Traction in Group I For longitudinal traction a weight equal to 1/5 of the body weight is used, e g., a traction weight of 14 Kg with a body weight of 70 Kg

In addition to the longitudinal traction, as soon as the patient has been taken to his room a well-padded lateral traction sling should be applied round the thigh on the injured side and a countertraction sling round the pelvis, each weighted with 4—5 Kg Counterpressure against the rim of the pelvis can be used instead of the pelvic countertraction sling This lateral traction is essential, since the femoral head is displaced medially (figs 1566 a—d)

Longitudinal Traction in Group II Longitudinal traction is applied as in group I, i e, with 1/5 of the body weight. Our experience has shown lateral traction in group II cases to be unnecessary, the femoral head displacement being mainly cranialward (figs 1567 a—e)

First Check Roentgenogram Six or, at the most, 12 hours after application of traction, a check roentgenogram of the whole pelvis should be made with the portable X-ray apparatus The lower limbs should be in as nearly as possible identical positions If continuous traction was applied on the day of the accident, the roentgenogram as a rule shows the femoral head to have been

pulled from its abnormally central position in the pelvis and the displaced pelvis fragments to have been reduced (figs 1566 d and 1567 e and g) Sometimes there is slight diastasis in the joint, which is desirable unless it exceeds 5—6 mm since it indicates that the femoral head has been relieved of pressure

Reduction by Lateral Traction on Both Thighs If in group I cases a medial subluxation persists, a folded sheet is put round each thigh and strong lateral traction is exerted from both sides, the patient being of course in bed and longitudinal traction continuing all the time Both lower limbs should be internally rotated.

If a roentgenogram of the whole pelvis is then made, it usually shows the fragments to have been reduced

If the traction weight is diminished too early after successful reduction, the femoral head and the pelvic fragments will slip back into their abnormally central positions in the pelvis By adding weight later one can pull the femoral head out again, but the fragments of the acetabulum remain displaced and arthrotic changes later develop

Consequences of Delayed Reduction If continuous traction is first applied as late as the third day or later, the femoral head can usually be pulled from the pelvis but the fragments of the acetabulum frequently do not follow it but remain displaced Therefore the femoral head slips back into the sunken acetabulum when traction is removed

Second Check Roentgenogram A view of the whole pelvis should be made two or three days after the accident and application of traction in order to see that good position has been retained and that diastasis in the hip joint has not become excessive If the diastasis exceeds 5—6 mm, the longitudinal traction weight should be reduced by 2—3 kilos Lateral traction weights should remain the same

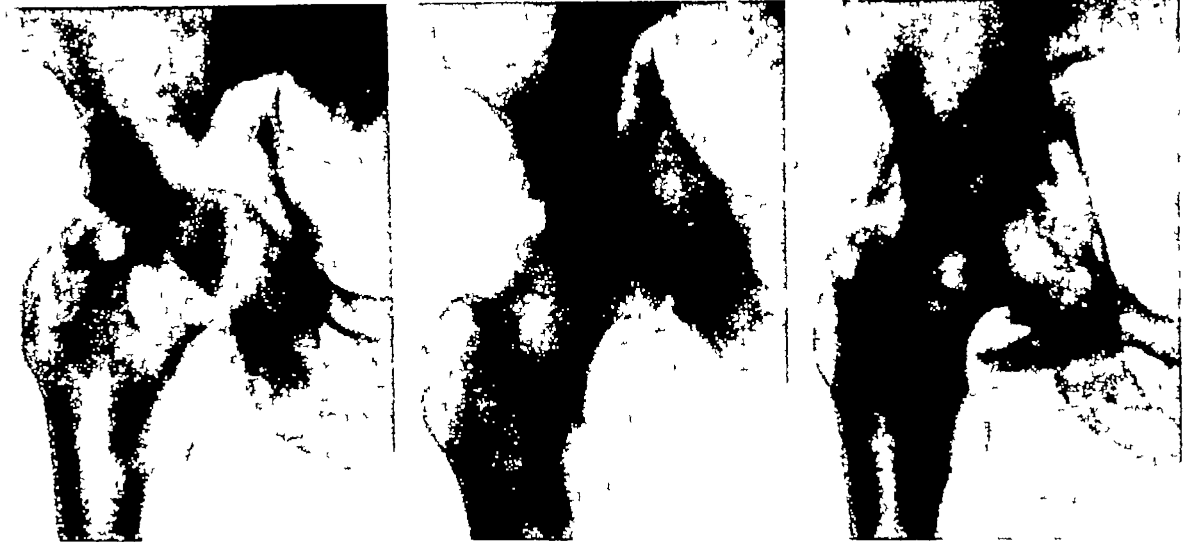
Further check roentgenograms should be made every week during the first month and every second week later on, with particular attention to be given the diastasis If it at any time exceeds 5—6 mm, the longitudinal traction weight must be reduced by 2—3 Kg. Since the muscles become progressively somewhat weaker, a longitudinal traction weight of 5 Kg will as a rule be sufficient toward the end of the first month Later even 3 kilos is often enough The lateral traction and countertraction of 4—5 Kg each must remain unchanged

Lateral skeletal traction through a screw in the greater trochanter or through a wire, as advocated by many authors, we use only exceptionally, since we have seen many cases so treated in which infections and fistulae have resulted Ordinary lateral traction with slings is nearly always sufficient We use screws only when the patient cannot tolerate lateral sling traction on the thigh because of thrombophlebitis or in the case of central dislocation of both hips

Reduction by Manipulation under General Anesthesia For a time we reduced central dislocations of the hip by abducting both lower limbs slowly and carefully under general anesthesia until the tips of the greater trochanters touched the pelvis, maintaining uninterrupted longitudinal traction

all the time Reduction was effected in this manner, but the results were in no way better than those with continuous traction (figs 1566 and 1567 b) There is, moreover, the danger with that manipulation method that in group I cases the femoral head, already injured in the accident, is liable to be compressed again In group II cases (fig 1567) that method of reduction cannot be used, the acetabular roof and the ilium in those cases being fractured and therefore unfit for providing the needed support

If reduction by manipulation under general anesthesia is carried out later than the second day, necrosis of the femoral head and severe myositis ossificans as a rule develop (fig 1567 h)



1567 f, November 16, 1949 — 1567 g, November 30, 1949 — 1567 h, September 15, 1951

FIG 1567 f — Roentgenogram of a nine day old central dislocation of the hip, Group I, with simultaneous fractures of the iliopectineal line, pubic bone and ischium

FIG 1567 g — Check roentgenogram re figure 1567 f, two weeks later Reduction was performed on the ninth day after the accident by strong manual traction in the long axis of the body and by maximum abduction Then longitudinal traction of 14 Kg and lateral traction of 5 Kg were applied The dislocation has been satisfactorily reduced In the cranial part of the femoral head at the lateral margin of the joint surface is a depression 10 mm wide and 4 mm deep which was caused by the impact of the femoral head on the medial fracture edge of the acetabular roof First roentgen signs of myositis ossificans are seen here caudal to the femoral head

FIG 1567 h — Check roentgenogram re figure 1567 f, two years later Myositis ossificans and necrosis with partial collapse of the femoral head because of the delayed reduction with forcible manipulation on the ninth day

Reduction by manipulation from inside the rectum, with Hegar's dilators, etc , should not be attempted because of the danger of damage to the rectum

Exercise therapy is used as with fractures of the femur in skeletal traction (see page 1265)

Time of immobilization According to the extent of the original displacement, the traction must remain for 10—12 weeks, or even for 14 weeks in unusually severe cases

Further treatment is carried out as with fractures of the femoral shaft (see page 1261)

Origin, Prevention and Treatment of Early Complications Following Central Dislocation of the Hip

Early complications are (1) death and (2) intestinal injuries

Fatalities can be avoided by treating any eventual shock promptly with local anesthesia and heat and, when necessary, with transfusion of blood or plasma Reduction in general anesthesia should be avoided.

Intestinal injuries must be recognized promptly and then the injured intestine must be promptly repaired (see Vol I/pp 477—486)

Origin, Prevention and Treatment of Late Complications Following Central Dislocation of the Hip

Late complications following central dislocation of the hip are the same as those following other types of hip dislocation, viz 1) Myositis ossificans; 2) Necrosis of the femoral head, 3) Arthrotic changes, and 4) Pain and limited motion

Cause, Prevention and Treatment of Myositis ossificans We have seen it only once in our 57 cases, viz, in a case in which reduction by manipulation was done late (fig 1567 h) We therefore avoid reducing by manipulation under general anesthesia, especially after the second day Once it has developed, myositis ossificans cannot be cured by any method of treatment

Cause of Necrosis of the Femoral Head Our experience indicates that necrosis of the femoral head after central dislocation of the hip develops only in group I cases, because in those cases the femoral head is depressed by the impact against the acetabulum during the accident probably in a way similar to that in other fracture-dislocations of the hip and then regains its earlier form after the injuring force has ceased to act (see page 1120 and fig 1565 a) In central dislocations of group II, however, the femoral head is not injured, which likely explains why we have never seen a collapse of the head develop later in any of the group II cases

Collapse developed in group I cases only when reduction had been delayed or when the femoral head, after satisfactory primary reduction, had slipped back into the pelvis because of insufficiently strong continuous traction

Prevention of Necrosis of the Femoral Head It can be prevented if the nature of the injury is recognized at once, if reduction is done gently on the first day by application of continuous traction strong enough to maintain in the joint continuous diastasis of 5—6 mm, and if continuous traction is maintained until firm bony union of the fragments has occurred

Treatment of Necrosis of the Femoral Head If persistent pain develops in addition to the limitation of motion and the contractures, arthrodesis (fig 1565 e) or arthroplasty (fig 1565 b) can be done

Origin, Prevention and Treatment of Arthrotic Changes They develop in all cases of necrosis of the femoral head in these as in other fracture-dislocations of the hip Slight arthrotic changes also occur without necrosis of the head in cases of both groups I and II, especially in cases in which

reduction had been incomplete or delayed They can therefore be prevented in most cases if accurate reduction by continuous traction is accomplished on the first day and if continuous traction is maintained long enough

Origin, Prevention and Treatment of Pain and Limited Motion Causes and treatment are the same as with other types of dislocation of the hip (see page 1127)

Questions We Should Ask Ourselves in Order to Avoid Mistakes When Treating Central Dislocation of the Hip

1 Have I *treated the shock* (if any) before making roentgenograms and before reduction?
2 Have I warmed the patient quickly with warm blankets, hot beverages and warmed air in order to treat the shock?
3 Have I given the patient local anesthesia in order to combat the shock?
4 Have I given a transfusion of blood or plasma if baking and local anesthesia were ineffective?
5 Have I, after having successfully combatted the shock, made an antero-posterior roentgenogram of the whole pelvis in accurate alignment, avoiding any degree of tilt or rotation?
6 Have I ordered the correct bed and all the necessary appliances in good time?
7 Have I used for longitudinal traction 1/5 of the body weight?
8 Have I applied lateral traction to the thigh of the injured side in dislocations of group I?
9 Have I applied countertraction or counterpressure to the pelvis in dislocations of group I?
10 Have I omitted lateral traction in dislocations of group II?
11 Have I made the first check roentgenogram after 6—12 hours in order to see whether the fragments have been well reduced and whether there is hip-joint diastasis of 5—6 mm?
12 Have I positioned the lower limbs symmetrically before making the check roentgenogram?
13 Have I tried reduction by manual lateral traction if the check roentgenogram still showed subluxation after 6—12 hours in spite of sufficient longitudinal traction?
14 Have I made a check roentgenogram on the third day in order to see that the diastasis was not excessive?
15 Have I diminished the longitudinal traction weight if the diastasis exceeded 6 mm?
16 Have I made check roentgenograms every week during the first month and every fortnight during the second month?
17 Have I diminished the longitudinal traction to 5 kilos toward the end of the first month if there was still a diastasis of more than 5—6 mm?
18 Have I avoided doing manipulative reduction under general anesthesia?
19 Have I avoided lateral traction with a screw in the greater trochanter?
20 Have I avoided attempting manipulative reduction of pelvic fragments from within the rectum, as with Hegar's dilators?

21. Have I had the patient do daily exercises?
22. Have I maintained the continuous traction long enough, i e., for 10—14 weeks?
23. Have I avoided massage and passive motion in subsequent treatment?

Results in 57 Central Dislocations of the Hip

In order to determine the influences of the manner of accident, the mechanism of the injury, the type of dislocation, the age of the patient, the method and time of reduction, the method of immobilization and the nature of subsequent treatment on the result, I asked Wechselberger[1] to do follow-up examinations in the 57 cases of central dislocation of the hip treated by us from 1926 to 1951 Five times within two years I reviewed with him all the roentgenograms in every case, each time from a different point of view

Distribution Among Groups Of these 57 cases, 32 (56%) belong to group I (figs 1566 a—d and 1567 f—h) and 23 (40%) to group II (figs 1567 a—e) Two cases (4%) were severely comminuted fractures belonging to group III

Concomitant Injuries Of the 57 cases, 26 (45 4%) had concomitant injuries outside the pelvis and 31 (54 6%) had not Two cases involved ipsilateral fracture of the femoral shaft

Distribution according to Age Cases published by Westerborn[2] are in parentheses

Age groups	Number of cases	Age groups	Number of cases
21—30	4 (4)	61—70	10 (0)
31—40	9 (7)	71—80	4 (2)
41—50	10 (2)	92	1 (0)
51—60	19 (5)		57 (20)

Most of our patients, viz , 34 out of 57, were more than 50 years of age, whereas most of Westerborn's patients were younger than 50 years of age In teenagers this injury seems not to occur at all, or at least very rarely

Reduction It was attempted in 53 of the 57 cases In the other four cases it was not attempted, because of the poor general condition of those patients.

In the 53 cases in which reduction was attempted, reduction was completely successful in 33 cases, partially successful in 20

Reduction was completely successful·

	group I	group II	group III
by extension only	18	8	0
by screw traction	1	1	0
by manipulation under general anesthesia	5	0	0

[1] Wechselberger Erfahrungen und Behandlungsergebnisse an 57 frischen Huftpfannenbruchen mit zentraler Luxation des Oberschenkelkopfes Ergebnisse der Chirurgie und Orthopadie, 1956

[2] Westerborn Beitrage zur Kenntnis der Beckenbruche und Beckenluxationen Acta chirurgica scandinavica, Vol LXII, Supplementum VIII, 1928

Reduction was partially successful·

	group I	group II	group III
by extension only	8	5	1
by screw traction	1	1	0
by manipulation under general anesthesia	2	1	1

In those 13 cases in which reduction by traction failed, the cause was either delayed admission to the hospital or the use of too little traction weight This seems to indicate that even severe central dislocations of the hip can be completely reduced provided they are diagnosed and reduced in time Reduction is achieved most easily and most gently by pin or wire traction with a weight equal to 1/5 to 1/6 of the body weight — enough to cause a hip joint diastasis of 5 to 6 mm In cases belonging to group I, lateral traction on the injured thigh and countertraction or counterpressure upon the pelvis must be used, since the head of the femur is displaced medially In cases of group II, strong longitudinal traction without lateral traction will do, as the femoral head is displaced cranially. Reduction in the screw traction apparatus or by manipulation is not necessary and after the first day is even dangerous, as it may cause avascular necrosis of the femoral head and/or myositis ossificans

Immobilization Good position obtained by reduction can be retained only by traction According to the degree of the primary displacement, the patient must remain for from 10 to 14 weeks in bed and in continuous traction sufficient to maintain the diastasis of 5—6 mm in the hip joint

Time of Observation Of the 57 cases, 37 could be reviewed after 2 to 21 years

	Group I	Group II	Group III	Total
Total number of cases	32	23	2	57
Number of reviewed patients	22	13	2	37
Time after injury in years	2—16	2—21	7—9	2—21

Of five more patients who did not come to the follow-up examination because they had died, clinical and X-ray findings from the time of the disability assessments are available Of those 50 patients who survived the period of treatment, 42 were followed for periods of at least four years

Early Complications. *Fatalities* Of the 57 patients, seven died during the treatment, i e, four on the first day because of severe concomitant injuries The fifth patient died on the twelfth day He had suffered a concomitant severe contusion of the brain with paralysis of his right side The sixth patient died of pulmonary embolism on the 16th day As concomitant injuries he had sustained a concussion of the brain, a fracture of the scapula and serial costal fractures The seventh patient died with pneumonia on the 17th day. He had suffered concomitant fractures of the sixth, seventh and eighth ribs Moreover, he had a pin track infection and a secondary arterial hemorrhage where the lateral traction was applied on the femur We no longer use pins or wires for lateral traction except in rare cases

We have not seen any of the *intestinal injuries* occasionally described by others

We have not seen any accompanying *vessel or nerve lesions*

Late Complications. *Myositis ossificans* occurred in only a single case, that one being in group I (fig 1567 h) The patient had been admitted on the sixth day and reduction was attempted by manipulation in anesthesia Shadows indicating the development of myositis ossificans were detected on the roentgenogram made on the 24th day Ankylosis of the hip joint in abduction developed later This lends support to the thesis that one should not attempt reduction by manipulation under anesthesia, particularly from the second day on.

Avascular Necrosis of the Femoral Head In the 22 reviewed group I cases we found avascular necrosis with depression of the head (fig 1567 f—h) to have developed in three and avascular disturbances of the femoral head without depression to have developed in five others All of these eight were cases in which admission and, therefore, reduction had been delayed. Among the 13 reviewed group II cases we found only one case of avascular disturbance of the femoral head, that of moderate degree and without depression In eight of the nine cases with avascular disturbances of the femoral head, traction had been maintained less than ten weeks This appears to have been one of the causes

Avascular disturbances of the femoral head

	Group I	Group II	Group III
Total reviewed cases	22	13	2
Number of avascular necroses with collapse	3	0	1
Number of avascular disturbances of the femoral head without collapse	5	1	1

From this we see that the group II cases are only slightly prone to avascular disturbances

Arhrotic changes developed in 20 of 37 cases, mainly in those which had not been completely reduced Of these 20 patients, 13 had slight, one had moderate and six had marked arthrotic changes

	Group I	Group II	Group III
Total number of reviewed cases	22	13	2
Number of patients with mild arthrotic changes	6	7	0
Number of patients with marked arthrotic changes	6	0	1

Clinical Results In spite of mild arthrotic changes and mild avascular disturbances of the femoral head, some patients had no complaints and almost unrestricted motion Of the 37 patients reviewed,

18 patients (48 6%) showed excellent or good results,
10 patients (27 %) showed fair results, and
9 patients (24.4%) showed poor results

Classification according to groups

	Group I	Group II	Group III
Total number of reviewed cases	22	13	2
Results excellent or good	12	6	0
Results fair	5	5	0
Results poor	5	2	2

Cases without complaints, with normal gait and free mobility are classified as "excellent" "Good" are those cases in which there are insignificant and merely temporary complaints and in which mobility is reduced only a little

"Fair" are those cases with temporary complaints, slightly limping gait, and mobility reduced not more than 50 per cent

"Poor" are those cases with reduction of mobility exceeding 50 per cent, with severely limping gait, and with pain on motion of the joint and especially on weight bearing

52. GUNSHOT WOUNDS OF THE HIP JOINT

Frequency Of gunshot wounds of the joints, those of the hip joints are the rarest They account for approximately 4 5 per cent

Classification Among his 55 cases, Jimeno Vidal [1] had 30 (54 5%) gunshot fractures of the femoral neck, 5 (9 1%) gunshot fractures of the acetabulum, 16 (29 1%) gunshot wounds of the hip joint without complete fracture of a bone (of the latter, 10 (18 2%) were lodging-wounds and 6 (10 9%) through-and-through wounds) and 4 (7 3%) empyemas of the hip joint after extra-capsular gunshot fractures of the femur

Fortunately, *nerve lesions* are rare in survivors. The sciatic nerve is much more often affected than the femoral nerve

Injuries of large vessels are rarely seen in survivors, since most patients with gunshot injuries of the femoral artery die on the battlefield and because injuries to the gluteal vessels occur only very rarely

Visceral injuries, especially of the large intestine and the urinary bladder, occurring concomitantly with a gunshot wound of the hip joint are so grave that in the past only few patients survived them even despite early surgical intervention as described in Vol I/page 497 Since the advent of antibiotics this has of course changed a great deal

Kinds of Wounds Most cases have small puncture wounds of entrance and exit, some have small puncture wounds of entrance but large wounds of exit, and some have no wounds of exit at all Those patients with extensive tissue destruction and loss usually die before treatment can be begun

TREATMENT OF GUNSHOT WOUNDS OF THE HIP JOINT

Treatment at the First-Aid Post and at the Clearing Station

Treatment of shock is given as quickly as possible, we relieve pain by chemical, thermal and mechanical means with injections, with heat applied

[1] Vidal, J Die Schußverletzungen des Huftgelenkes, mit besonderer Berucksichtigung der Schenkelhalsschußbruche (Erfahrungen aus dem spanischen Burgerkrieg 1936—1939) Arch orthop u Unfall-Chir *41* 605—648 1941

externally and internally and with immobilization (Vol I/p 134) Hemorrhage must be arrested prior to the immobilization

Arrest of Hemorrhage and Dressing of the Wounds. Patients with hemorrhage from the femoral artery usually die on the battlefield and do not reach the main clearing-station Hemorrhage from smaller vessels is arrested by compression bandages In applying compression bandage one should see to it that the entire pelvis, and especially the inner side of the thigh, are well and equally padded with cellulose The coils of the bandage are pulled tightly but must not touch the bare skin anywhere lest they cause intolerable pressure pain If, in spite of this, the hemorrhage is not stopped, we try to clamp visible spurting vessels The hemostats are then left in situ If clamping is impossible, we may in exceptional cases pack the wound tightly with sterile gauze provided that we know with certainty that the pack will be removed after a few hours If the pack is not removed it will prevent evacuation of the wound secretions and will lead to severe wound infection The insertion of such a pack must be marked on the field medical card as well as on the dressing itself, so that it will not be overlooked at the main clearing-station

Analgesia Since this injury is as a rule very painful, one must administer morphine and other analgesics in sufficient quantity unless there is intraperitoneal injury

Application of Heat Patients who have lost a great deal of blood and who are in shock must be wrapped in warm blankets and given hot drinks (if available) provided there is no abdominal injury Clothes should never be cut off but should only be opened lengthwise As soon as the wound is dressed they must be put on again and closed, lest the patient be chilled Moreover, the clothes serve as padding for the splint

All wounded men who have not been rendered actively immune should receive **tetanus antitoxin.**

If *penicillin* is available it should be given.

Dressing for Transport to the Main Clearing Station or the Field or Base Hospital In gunshot wounds of the hip joint, perfect immobilization can be achieved only by a plaster cast reaching from the axilla to the toes on the injured side and as far as the knee on the sound side It is impossible, however, to apply such a plaster cast at the first-aid post If transport extension splints are available, one should use them They do not, however, immobilize completely It is better to apply a bandage with well-padded Cramer or wooden splints This bandage is effective only if it extends from the axilla to the sole of the foot and if it has a transverse bar under the heel which prevents foot drop and external rotation of the foot This bandage, too, provides only imperfect immobilization In most cases all one can do is to place some padding between the knees, tie both legs together and put a folded blanket or a knapsack beneath the knees for support Stigler's [1] mountain stretcher on which the patient sits with flexed hip and knee joints affords fairly good immobilization

[1] Stigler Eine zusammenklappbare Gebirgsbahre fur Friedens- und Kriegszwecke Wien med Wchnschr *13* 1938

Questions We Should Ask Ourselves to Avoid Failures in Treating Gunshot Wounds of the Hip Joint at the First-Aid Post and at the Main Clearing Station

1 Have I arrested hemorrhage by application of a sterile compression bandage?
2 Have I alleviated pain by injection of suitable drugs in adequate amounts?
3 Have I, if blankets were available, covered the patient well and at once?
4 Have I, provided no abdominal lesion had occurred, supplied the patient with hot drinks, if possible?
5 Have I refrained from cutting up the clothes more than necessary?
6 Have I padded the femur and the pelvis well before applying the compression bandage?
7 Have I applied a clamp to visibly bleeding vessels if the hemorrhage could not be arrested by a compression bandage?
8 Have I packed the wound tightly with sterile gauze if hemorrhage could not be arrested by any other means?
9 Have I given tetanus antitoxin to those patients not actively immune to tetanus?
10 Have I given penicillin?
11 Have I, if I have used a pack, marked it visibly and clearly on the field medical card and on the bandage?
12 Have I immobilized the hip joint by well-padded Cramer or wooden splints?
13 Have I applied a transverse bar under the heel to prevent the foot from falling and the leg from rotating externally?
14 Have I, if no splints were available, tied both legs together after having placed some padding between the knees?
15 Have I then placed a knapsack or a blanket under the knees?

Treatment at the Main Clearing Station or at the Field and Base Hospital

Treatment of Shock The patient is warmed by baking and with blankets Analgesics and hot drinks may be given only in the absence of abdominal injuries In case of low blood pressure and raised pulse-rate, blood should be given

Diagnosis of Injuries to the Rectum, the Urethra, the Urinary Bladder and the Abdominal Viscera Owing to the proximity of the hip joint to pelvic and abdominal viscera, it may happen that these structures also are injured with injuries to the hip Consequently we should always be on the lookout for such injuries, an oversight is generally fatal In through-and-through wounds we can judge from the course of the missile whether pelvic or abdominal viscera were injured In lodging wounds this judgment is impossible without roentgenograms Hemorrhage from the anus or the urethra suggests injury to these or associated structures

Blood issuing from the urethra may have its origin in the urethra, the bladder, the ureter or the kidney (Vol I/fig 617) As with all pelvic injuries, one should ask the patient to pass urine If this is impossible the patient must

be catheterized If a catheter cannot be passed into the bladder, the urethra has likely been injured If a catheter enters easily into the bladder, drawing off thereafter only a few drops of blood and urine, the bladder is injured either intraperitoneally or extraperitoneally A great deal of blood and strongly blood-stained urine from the bladder suggests an injury to the kidney (Vol I/fig 617)

If blood is coming from the rectum, a rectal examination must be performed digitally or with the proctoscope (Vol I/fig 618)

The symptoms and signs of intraperitoneal injuries are described in Vol I/pp 477—485

The treatment of concomitant intestinal injuries is discussed in Vol I/pp 477 until 498.

Diagnosis of Gunshot Wounds of the Hip Joint. As with all other injuries we first must examine the knee-jerks, test the reactions of the pupils, palpate the pulse on the dorsum of the foot and behind the medial malleolus, and check sensibility and active mobility Because of the thick cover of soft tissue, it is more difficult to diagnose gunshot wounds of the hip joint than of other joints In through-and-through wounds we may conclude from the path the missile has taken whether the hip joint has been penetrated, in lodging wounds this is impossible With a simultaneous fracture of the femoral neck the limb will usually be externally rotated through 45° to 60°, while with pertrochanteric fractures external rotation generally amounts to 90° so that the outer side of the foot lies on the bed Moreover, pain is felt if pressure is applied to the heel in the long axis of the leg, as well as on traction and torsion, and there is also local tenderness on pressure Fractures of the acetabulum, and the nature and extent of lodging wounds and of through-and-through wounds without complete severance of the upper end of the femur, can be diagnosed reliably only with roentgenograms The positions of lodged bullets can be determined only if we also have good lateral views, as in figures 1532 c, 1705 and 1707 A lateral view involving a minimum of pain to the patient is obtained in litothomy position (fig 1596) The clinical signs, such as limitation of motion and presence of pain upon pressure, may not be turned to account, since they occur as well in soft-tissue injuries not involving the joint Recognized leakage of synovial fluid is unlikely to occur

Complicating Factors with Gunshot Wounds of the Hip Joint There are the dangers of *infection* and *secondary hemorrhage* Both may lead to death. By primary débridement of the wound and early accurate arrest of hemorrhage prior to infection, combined with antibiotics, we are able to reduce these two dangers considerably

Definitive Arrest of Hemorrhage In all patients in whom a gauze pack or a clamp has been used for temporary control of hemorrhage, and in all patients who continue to bleed, one must arrest hemorrhage definitively as soon as one has successfully combatted shock and has taken care of any concomitant intestinal injuries In recent injuries with small entrance and exit wounds, and in lodging wounds, we must not overlook any firm, rounded swelling on the buttocks Such localized swelling generally indicates an injury to the superior or inferior gluteal artery

As it is sometimes difficult to find the bleeding vessels, it is expedient to prepare to use Momburg's method of compression of the abdominal aorta so that one can use it immediately in case of need. Then the path the missile has taken in the body is widened. Spurting vessels are clamped centrally and peripherally from the site of the injury and are doubly ligated.

Débridement. Thorough débridement and immediate arrest of hemorrhage afford the best possibility of avoiding infection and secondary hemorrhage. Here the antibiotics are a valuable help, but they are no substitute for an exact wound excision.

Small, "caliber-size" puncture wounds of entry and exit must be neither excised and sutured nor simply sutured, since this causes tension in the tissues and predisposes to infection. In large through-and-through wounds and in lodging wounds, all lacerated, contaminated and devitalized tissue should be excised, preferably under *local anesthesia*. Thus most of the pathogenic micro-organisms will be removed. In the excision of wounds the rules given in Vol. I/pp. 142—174 should be observed, but such thorough procedure will rarely be possible. Wound excision with the scalpel must be adequate and must be carried out rapidly. The arrest of hemorrhage must be thorough. With deeper wounds, collateral dependant drainage is afforded by a soft rubber drain or a rubber tube. Wound cavities must not be plugged with gauze, since there is great danger of gas-gangrene in such wounds. Without excision of the wounds, severe infection frequently develops in the thick muscular tissue of the buttocks. **The femoral head must not be removed at the first débridement of the wound,** since generally we have found infections to have been much worse after primary than after secondary removal of the femoral head. After excision of the wound we instill penicillin. **Suture of the wound is as a rule prohibited.**

Primary resection of the joint with excision of the femoral head and of the acetabulum is out of the question, because it is an extremely dangerous and mutilating operation.

Primary disarticulation of the femur should be performed only in case of a severed femoral artery and the most severe lacerations of soft tissues. It may only be considered if blood can be given, for otherwise most patients will die from the operation.

On theoretic grounds, suture of the joint capsule is frequently recommended, but in practice it can hardly be performed in the hip joint.

One should refrain from *attempts to sterilize the joint* by conventional chemical means. They have not been successful, in my experience. Use of the new antibiotics is effective.

Avoidance of Wound Infection. The best way to avoid infection is to afford complete, uninterrupted immobilization of the hip joint, the entire injured limb and the sound limb down to the knee joint after thorough débridement of the wounds with the scalpel. Patients with noninfected gunshot wounds of the hip joint with small wounds of entry and exit should of course also be put in large plaster casts for transportation.

Preparation for Transportation to the Special Army Hospital. After débridement by scalpel, patients with gunshot wounds of the hip joint should

be transported in an immobilizing bandage as quickly as possible (preferably by plane and without intermediate stop-over) to a special army hospital for fractures and gunshot wounds of joints, where they may stay uninterruptedly until their treatment has been completed The best transportation bandage is a padded and windowed thoracopelvic hip spica including the thigh of the sound side

If there is danger of hemorrhage from the branches of the femoral artery, one should, before applying the cast, place a tourniquet loosely round the proximal part of the thigh and lead it out from the cast proximal to the greater trochanter To prevent displacement of the tourniquet, its ends are secured by two gauze bandages For the application of the plaster cast we use a screw traction apparatus as in figures 1577 and 1696 if it is available, Any other traction apparatus would serve If no traction apparatus is available, we place the patient on a pelvic support and the injured limb on two little tables as shown in figures 1627 to 1634 The distance between the heels should not exeed 40 to 50 cm Abduction should accordingly be only moderate, because a strongly abducted limb is very awkward in transportation The plaster cast must extend from the axilla to the toes

The application of the plaster cast and the material required for it are described in detail on page 1214

Cutting Windows in the Plaster Cast. If one uses the method described in Vol I/609, large windows must be cut in the cast above the wounds so that one may be able to dress and to inspect the wounds without interrupting the immobilization The windows should always be quadrangular rather than round, in order to facilitate the cutting of the pads necessary for dressing the wounds

Marking the Plaster Cast The field medical card of the wounded is frequently lost or becomes illegible Consequently the following data should be marked on the dressing itself: day and hour of injury; day and hour of last treatment (wound excision, arrest of hemorrhage, etc); a sketch showing site and size of the wounds and site and nature of the fracture, notes on special features, e g , danger of hemorrhage or gas-gangrene, the name of the surgeon and his unit in order that he might possibly be reached if necessary

Questions We Should Ask Ourselves to Avoid Failures in Treating Gunshot Wounds of the Hip Joint at the Main Clearing Station and the Field or Base Hospital

1 Have I, provided no intestinal injuries have occurred, treated the shock by supplying the patient with internal and external heat (hot drinks, warm blankets, baking) as discussed in Vol I/page 134?
2 Have I given adequate analgesic, provided no contraindicating abdominal injury had occurred?
3 Have I given blood in case of low blood pressure and rapid pulse-rate?
4 Have I catheterized the urinary bladder in case of suspected injury to the urinary tract?
5 Have I done a rectal examination in case of suspected injury to the rectum?

6 Have I, on suspicion of intraperitoneal injury, examined for rigidity of the abdominal wall?
7 Have I noted the form and the color of the involved limb?
8. Have I taken the pulse on the dorsum of the foot and behind the medial malleolus?
9 Have I taken appropriate roentgenograms?
10. Have I in packed wounds arrested hemorrhage by ligation?
11. Have I prepared for eventual use of Momburg's method of temporary control of bleeding prior to attempting to arrest the bleeding by other means?
12 Have I refrained from excising and suturing small projectile wounds?
13 Have I refrained from simply suturing small projectile wounds?
14 Have I excised the wounds while they were fresh?
15 Have I excised only the most definitely devitalized parts and removed only visible foreign bodies in wounds of long standing?
16 Have I given penicillin locally and systemically?
17. Have I **abstained from suturing the excised wounds?**
18 Have I, if there was danger of hemorrhage, applied a tourniquet round the thigh before applying the plaster cast?
19 Have I applied the plaster cast from the axilla to the toes and have I included the sound limb down to the knee?
20 Have I seen to it that the distance between the heels did not exceed 50 cm ?
21. Have I cut appropriate windows in the plaster cast?
22 Have I marked the plaster cast properly?

DEFINITIVE TREATMENT OF GUNSHOT WOUNDS OF THE HIP JOINT AT THE SPECIAL HOSPITAL

Treatment of Shock First, the "transportation shock" ought to be treated by internal and external applications of heat (hot drinks, warm blankets, baking, see Vol I/p 134) and by nourishing food If necessary, i e, in case of low blood pressure and rapid pulse-rate, blood should be given If no urgent treatment is required, the patient should be allowed to sleep

Retention of the Immobilizing Bandage The strain and the jarring of transportation cause many patients with gunshot wounds of the hip joint to have elevated temperatures when they are admitted to the special army hospitals If the immobilizing cast fits well, if the wounds appear to have been well treated and show no evidence of developing infection, and if position and alignment of the fracture fragments are good, the transportation cast may occasionally be allowed to remain throughout the whole treatment In view of the danger of typhus and for the purpose of delousing, we formerly had often to remove plaster casts so as to be able to clean, shave and delouse the patients Thanks to DDT one can now leave the casts in place If the patient's fever does not relent on the day after admission, windows are enlarged so that one can see whether a phlegmon or an abscess has developed If pus formation is not too great one may open a discovered abscess without removing the plaster cast

Case History In a patient with a small entry wound close to the sacrum and an exit wound four to five cm in diameter anterior to the greater trochanter, wound excision with the scalpel was performed five hours after the injury Then immobilization was afforded with a big plaster cast extending from the axillae to the toes with an appropriate window above the anterior wound Owing to transportation difficulties, he stayed in the field hospital for four days Then railroad transportation was provided to the special army hospital, which was 450 Km distant On admission there the patient had a temperature of 39 5° C, slight pain, moderate suppuration, vicinity of wound not reddened Roentgenograms showed a comminuted fracture of the entire trochanteric region and the neck of the femur General alignment good Patient was free from lice Therefore, the plaster cast was left After three days the temperature dropped to 38° C As the plaster cast was rather weak near the window, it was reinforced by thick posterior and anterior plaster splints After one week of fever, temperature sank to 37 5° In the fourth week the temperature rose to 38 5° and the wound showed dirty granulations and began to suppurate profusely The window in the plaster cast was enlarged, after which a soft-tissue prominence could be seen behind the greater trochanter Upon pressure on this prominence, a great deal of pus issued from the anterior wound Under short general anesthesia a longitudinal incision five cm long was made over this prominence and the wound and abscess cavity were explored digitally No further pockets were found The patient was afebrile on the following day Never during the subsequent weeks did his temperature exceed 37 6° Roentgenograms were made every four weeks and always showed good position of the fragments After ten weeks the wounds were healed except for two small discharging sinuses on the posterior side After four months the patient was allowed up in the plaster cast After eight months the plaster cast, which had been applied on the day of the injury, was removed Ankylosis of the hip in good position with an abduction of 10° had resulted The comminuted fracture of the femoral neck and the trochanteric region had healed in good alignment Four weeks later the ankle joint motion was free and the knee could be moved from 180° to 90° The patient could walk without even a stick

Roentgen Examination. Roentgenograms should be made only after the patient has recovered a little from the stress and strain of the transportation Anteroposterior and lateral roentgenograms should then be made so that one can determine the type of bone injury and can know as accurately as possible the shape and position of the fragments

Plaster Cast or Traction Bandage? Transport plaster casts are generally not applied well enough to warrant their being left permanently If they are full of lice, if they do not fit or if they are broken, they should of course be removed The best thing to do then is to replace them immediately by new plaster casts If there is a great rush of wounded, however, this will not be possible, since the application of a perfectly-fitting thoracopelvic hip spica and the cutting of the proper windows requires from one to two hours In such situations it is best to place the limb on a Braun splint (fig 1604 a) or on a thigh splint (fig 1605) and to apply traction with a pin or wire put through the tibial tubercle under local anesthesia If the bed and all accessories are properly prepared, application of this treatment should require only ten minutes Aseptic cases may remain in traction, but with infected cases it is better to apply a big plaster cast after thorough exposure of the foci of infection

Treatment of Aseptic Gunshot Fracture of the Femoral Neck

If the transportation plaster cast does fit well and if there is no other reason for removing it, it ought to be allowed to remain for four weeks, even in fractures of the femoral neck with displacement, because they can be reduced in a traction bandage as easily and as well after four weeks as on the

first day If the transportation plaster cast is inadequate it ought to be removed at once. If one leaves the joint without immobilizing support in gunshot fractures and lodging gunshot wounds of the hip, incautious and excessive motion may cause reactivation of dormant infection or even the development of acute infection as late as the third or fourth week One ought, therefore, to be cautious in allowing movement

Subsequent Treatment of Gunshot Wounds of the Femoral Neck After removal of the transportation plaster cast, the limb should be placed on a Braun splint, a pin or wire should be passed through the tibial tubercle, and continuous traction should be exerted with a weight equal to one-tenth of the body weight After a few hours one should carefully turn the leg into internal rotation This traction treatment is carried out in exactly the same way as in simple fracture of the femoral neck (see page 1210)

Extra-articular Nailing of Gunshot Fractures of the Femoral Neck If the alignment of the fragments is good and if the patient has been afebrile and has not shown any indication of inflammation except on the first and second days, we may, provided the erythrocyte sedimentation rate is normal, do extra-articular nailing eight weeks after injury under penicillin cover as in simple fracture of the femoral neck (see page 1256) In fractures of the femoral neck resulting from lodging projectile wounds we remove the projectile eight weeks after injury if the erythrocyte sedimentation rate is normal Nailing is then done four weeks later after preliminary treatment with penicillin Jimeno Vidal has nailed nine of twelve gunshot fractures of the femoral neck, eight of them with complete success. He lost one case through sepsis associated with faulty material I have nailed fourteen pseudarthroses following aseptic gunshot fractures of the femoral neck In most cases the result was bony union and good function

Treatment of Gunshot Fracture of the Femoral Neck in Plaster (Whitman, Lorenz, Lofberg) If we lack the technical means necessary for nailing we may apply a plaster cast extending from the axillae to the toes of the injured limb (as in figures 1626—1640) with extreme abduction and marked internal rotation It should be removed six months after injury at the earliest

Treatment of Aseptic Gunshot Fracture of the Acetabulum

If the transportation plaster cast fits well it should be allowed to remain, otherwise it should be removed After four weeks the patient may get up in the cast and walk about The plaster is then removed eight weeks after injury During this time, bony union of the fragments (which are never excessively displaced in aseptic cases) generally occurs

Treatment of Aseptic Lodging Wounds of the Hip Joint

In lodging wounds of the hip joint the transportation plaster cast is left for four weeks provided it fits well, otherwise it is removed at once. Then the limb is placed on a properly dressed Braun splint and slight traction is applied through a gaiter, as demonstrated in figure 1577 Good anteroposterior and lateral roentgenograms show the exact location of the projectile If the projectile is in the joint, so that it is likely to reduce joint mobility later on,

it should be removed In puncture wounds which have always been dry the operation should be delayed for at least two months, in granulating wounds it should not be done before two months after epithelization, and then under penicillin cover, lest inflammation of the joint result If the projectile is outside the joint it should be removed only if it causes pain or other disturbance

Most projectiles lie anteriorly One is able to reach them through an incision between the sartorius muscle and tensor fascia latae distal to the anterior superior iliac spine One then retracts the rectus femoris medially, ligates the vessels lying transversely on the vastus lateralis and opens the joint capsule longitudinally. In posterior lodging wounds one makes an oblique incision in the direction of the fibers of the gluteus maximus muscle After removal of the projectile, new roentgenograms are made to ascertain whether one has removed everything We use a rapid film developer to avoid having the wound open for any longer time than-necessary (see page 1253) We leave a drain brought out through a stab wound, instill penicillin through it and then remove it after 24 hours As a rule we suture only the skin and do not suture the joint capsule Then we place the limb on a Braun splint for 3 weeks The patient may get up after that time and walk After this period of time, free motion of the joint may be expected

Treatment of Aseptic Through-and-Through Wounds of the Hip Joint Without Bone Fracture

One can recognize these wounds by noting the path of the missile They can otherwise hardly be diagnosed clinically, since they usually do not show pain upon impaction pressure, traction, torsion or local pressure Because of the covering of soft tissues, one can never see escaping synovial fluid The bony continuity is, of course, not interrupted, so that the gait is not impaired considerably In the roentgenogram, though sometimes only after films in several projections have been made, one sees a more or less deep groove in the femoral neck or head and in very exceptional cases a rather "clean" hole right through the bone ("button-hole" fracture)

For an injury of this kind it suffices if one supports the limb on a Braun splint for four to five weeks, provided the bone is intact Otherwise the patient should be kept in bed for eight weeks After such time the gait is usually normal

General Remarks on Treatment of Infected Gunshot Wounds of the Hip Joint

Of 55 gunshot wounds treated by Jimeno Vidal, 30 (54 54%) were infected Six (67%) of my nine cases were infected, as were 67% of Wustmann's cases

Infection of the hip joint is even more dangerous than infection of the knee joint Prior to the introduction of antibiotics, 20 to 35 per cent of the afflicted patients died In survivors we frequently find pathologic dislocations, abduction and flexion contractures, pseudarthroses, ankyloses and limitation of motion, and flail-joints resulting from extensive resection Of the sequelae,

flail joints, pathologic dislocations and contractures can usually be avoided by adequate treatment Ankylosis in good position is the best end-result

The most important things in the treatment of every infected gunshot wound of the hip joint are that there be adequate drainage **and uninterrupted immobilization** in a cast extending from the axillae to the toes on the injured side and including the sound thigh, and that there be adequate and rational administration of antibiotics Exercises of all the joints not included in the cast and in fact of the entire body must not be neglected

Treatment of Empyema of the Hip Joint by Immobilization and Aspiration Alone In the past we have occasionally seen regression of symptoms of infection and recession of fever in serous and purulent inflammations of the hip joint achieved even without penicillin by aspiration of the joint with the patient still in the transportation cast

Treatment of Empyema of the Hip Joint with Antibiotics In this case, too, we leave the transportation cast if it is in good condition and if there are no indications of a spreading infection We aspirate the joint and inject penicillin into it daily and, in addition, give penicillin systemically until the patient has been afebrile for two or three days The first aspirated fluid should be examined for sensitivity of the contained organisms to antibiotics

Removal of the Femoral Head If the temperature does not fall after perfect immobilization and administration of antibiotics and if the roentgenogram shows a fracture of the femoral neck or fragmentation of the femoral head and/or the acetabulum, the cast should be removed and the joint exposed freely through a big, oblique, posterior incision Before and during the operation, blood should be given After the joint has been opened it should be explored digitally and the fractured or crushed femoral head and any loose bone fragments of the acetabulum should be removed In infected cases the femoral head can never heal but remains as a sequestrum leading to the formation of a persistently discharging sinus and delaying or preventing the desired ankylosis If the suppuration is not of long standing, the ligamentum teres may still be more or less intact It is cut through with a curved scissors and then one is able to pull out the femoral head with a bone forceps In cases of long-standing suppuration that ligament is always destroyed, so that the femoral head lies free in the joint By extracting the femoral head we do not produce new raw surfaces on the bone as in a resection After we have extracted the femoral head and removed all bone fragments, we insert a thick rubber tube into the joint cavity and fasten it with two thin wire sutures If there is a wound on the anterior side we must insert a drain there as well, though in such case one should never use a through-and-through drain because its continued presence may hinder the desired ankylosis

In the case of mere empyema of the hip joint and phlegmon of the capsule, only the caudal quarter of the femoral head is removed in order to allow better drainage, as suggested by Lawen [1]

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[1] Lawen Über die Teilresektion des Huftgelenkes bei Eiterung nach Kriegsschußverletzungen Zentralbl f Chir 69 1446–1449, 1942

Drainage of Para-Articular Abscesses. If virulent infection has lasted over a long period, pus ultimately bursts through the capsule; whereas in low-grade infection the suppuration remains limited to the joint. The infection spreads anteriorly under the inguinal ligament, medially towards the proximal part of the adductors and posteriorly under the gluteal muscles at the distal end of which it "presents." The site of infection should be exposed by wide incisions. In abscesses on the anterior side a wide posterior counter-incision must always be added.

In cases of *gas phlegmon* or *malignant edema* numerous longitudinal incisions close to each other and extending into the sound parts should be made. If one drains all abscess cavities thoroughly by long and deep incisions, one generally succeeds in stopping this dangerous infection.

In *genuine gas-gangrene,* which is particularly frequent in the thick gluteal muscles if the wounds are not carefully débrided with the scalpel, all intervention was in vain in the past. In genuine gas-gangrene, in which no pus formation occurs, I have never seen any success from the use of gas-gangrene serum. Perhaps the prognosis is now better with the use of penicillin and other antibiotics.

Secondary resection of the joint with partial or total excision of the acetabulum and the femoral head should never be done. In my opinion it is an extremely dangerous operation which only a few patients survive if the infection is severe. In cases with minor suppuration and good general condition the operation is completely superfluous. It is done in order to secure good drainage for pus. In true resections the acetabulum is chiseled off and the femoral head and neck are removed, with fractures of the trochanteric region the greater trochanter and occasionally even a part of the shaft of the femur are removed. Thus large, new raw bone surfaces are created. If we read case histories dealing with the consequences of such operations we see that the patient's temperature usually rises postoperatively and remains elevated for a long time and that there follows the development of para-articular abscesses and extremely dangerous suppurations in the pelvis which normally do not occur in gunshot wounds of the hip joint without fracture of the acetabulum. I have seen a case in which thrombosis of the femoral artery and gangrene of the lower leg followed the resection. The mortality rate is and has always been extremely high. Langenbeck, the master of resection, reported a rate of over 83.87 per cent, the medical report on the American Civil War reported a mortality rate of over 93.6 per cent, and the German medical report on the war of 1870—71 one of over 92.7 per cent. In World War I the mortality rate was equally high. In any case, function is always severely impaired after an extensive resection.

Disarticulation also is a dangerous operation. In the past only few patients survived it. It is also a mutilating procedure and should therefore be considered only in exceptional cases.

Blood Transfusion. If the wounded are severely weakened owing to the severity of the injury and the virulence of the infection, one should give a blood transfusion of 200 to 500 ml. before and more during the operation. For

the operation itself everything must be well prepared so that it may be done as speedily as possible

Immobilization in Plaster. After removal of the femoral head, thorough exposure of all pus cavities and institution of adequate drainage with firm rubber tubes, spreading of the infection can best be prevented by complete and uninterrupted immobilization To this end we apply a plaster thoracopelvic hip spica with large windows bridged by Cramer wires, the cast extending from the axillae to the toes on the injured side with the whole as demontrated in Figures 1626 to 1640 If the femoral head has been removed, one should put the femoral neck into the acetabulum lest persistent dislocation result Such dislocation also occurs if one fails to provide sufficient abduction The sound thigh down to the knee should be included in the plaster cast Internal rotation of the limb as required in simple fractures of the femoral neck is not necessary Then we cut windows in the cast according to the size of the wounds If the infection seems likely to spread we cut windows of 20 to 30 cm over the buttocks, and then to prevent the cast from breaking we place two 50-cm -long walking-irons over the window and incorporate them in the plaster (Vol I/Fig 143) We bend them up 10 cm high on both sides so that we can easily approach the wound under them when changing the dressing (fig 2166 e) On the lateral side a strip of plaster cast of a hand's width should be left either anteriorly or posteriorly depending on the site of the wound, and this must be reinforced adequately Thus we achieve perfect immobilization and the entire hip region is free for examination so that we cannot overlook any spreading of the infection or newly developing abscesses As a result of such immobilization, particularly if combined with simultaneous administration of antibiotics, the temperature will usually fall after a few days

Immobilization in Traction Sometimes, if the wounds are too extensive, one cannot apply a plaster cast In such cases we place the limb on a Braun splint and exert skeletal traction as in figure 1604 In this way we achieve a certain though incomplete immobilization, the region of the hip joint being slightly moved especially during evacuation of the bowels or when the dressing is changed Nursing is, however, much easier with the patient in traction than with him in a plaster cast

Further Treatment of Infected Gunshot Wounds of the Hip Joint

Treatment of the Wounds Some attach great importance to the application of various ointments. The essential and most important treatment, however, is complete and uninterrupted immobilization after thorough drainage of the infected foci If the temperature falls and if the general condition of the patient is good, it is best to leave the dressing as long as possible, i e , for one week or longer In order to protect the skin from eczematoid eruption and the plaster cast from moisture, the area around the wound is covered with a thick layer of zinc paste This skin treatment should be carried out with great care, since secretions from eczematoid skin changes finding their way into the wound irritate it and cause in turn more wound discharge and deterioration of the eczema If, on the other hand, one keeps the skin dry, the

wound itself will heal more rapidly. We administer antibiotics at the same time

Protection of the Cast. The cast must also be kept dry For this purpose we cover the edges of the cast with water-proof cloth and place over them gauze sponges which have been covered by a thick layer of zinc paste If, in spite of this, the plaster becomes moist, we dust it with boric acid powder to dry it and to prevent pyocyaneus infection and foul odor In this way one usually succeeds in avoiding having to change the plaster cast, thus maintaining continuous and uninterupted immobilization

Prevention of "Window Edema" If we were to use a "no-dressing" treatment with these wounds of the gluteal region, a protrusion of the soft tissue through the windows would soon result This happens also if dressings are used but are not put on tightly enough The edges of the plaster cast round the window then cut into the skin and cause pressure ulcers In order to prevent these complications one must cut the dressing to be put on the wound in such a way that it will fit exactly into the window and will leave no empty space along the edges of the window The window should be quadrangular and not round, so that the dressing can be cut conveniently into the right shape and size The bandages must then be so applied as to provide compression sufficient to prevent any protrusion of the soft tissues We dust every layer of gauze with boric acid to prevent the bandage from developing a bad odor in cases of prolonged treatment If there is no acute inflammation it is often preferable to leave the plaster cast closed for several weeks and to abstain from cutting windows on the dependent side

Treatment of the Window Edema If a window edema has already developed one can eliminate it most quickly and comfortably by filling the window with a properly trimmed piece of sponge rubber on which we apply the necessary pressure with circular bandages

Exposure and Drainage of New Abscess Cavities. If despite a thorough primary exposure of the infected foci and the administration of penicillin, the temperature fails to drop or begins to rise again, we must explore the wound digitally in search of new wound pockets which are likely to develop in the thick muscular tissues If much pus is evacuated by pressure anywhere, a new incision must be made there — if possible without removal of the cast (see case history on page 1150) The cast should be covered carefully lest it become stained with blood when the incision is made

Secondary hemorrhage is rare in complete, uninterupted immobilization. It may result, however, from detachment of a thrombus or from erosion of an uninjured vessel by a drain or by a bone splinter If it occurs one must ligate the spurting vessel It is not enough to pack the wound Hemorrhage from the branches of the gluteal artery may be rather severe. If one fails to find the bleeding vessel or is unable to ligate it properly in the devitalized tissue, one must expose the hypogastric artery by an incision running parallel to the inguinal ligament and must ligate it retroperitoneally. The hypogastric artery branches off from the common iliac artery at its point of entry into the true pelvis and thereafter crosses the sciatic and obturator nerves The ureter lies anterior to the artery

Removal of Projectiles. If metal splinters are present in the hip joint they should be removed at the time of the removal of the femoral head or at the time of drainage of abscess cavities. One should not attempt otherwise to remove them. If, after bony union has occurred, they cause a discharging sinus they must be removed. This can often be done with the Volkmann spoon.

Prevention of Flail Joints. They occur only after extensive resections of from 5 to 10 cm. of the femoral shaft, as has been described by some authors. As a rule the limb is then useless and has to be amputated. In exceptional cases it is possible to obtain ankylosis with big bone grafts.

Prevention of Pathologic Dislocations. They may occur in any severe infection of the joint. The ligamentum teres is often destroyed by the infection after only a few days. If neither a plaster cast nor traction was applied, abduction and flexion deformity will result. Then the femoral head, pushed out by the joint effusion, slips out of the acetabulum at its posterosuperior side. Various pathological dislocations are caused by resection or destruction of the joint. With suitable traction or casts one can always prevent these serious conditions which so markedly impair the function of the limb.

Prevention of Deformities. After every inflammation and injury in the hip joint, flexion and adduction contracture occur even without pathologic dislocation of the hip, as shown in figures 1931, 1932 and 1953—1958. One can prevent such deformities only with traction or plaster casts applied with the limb in a suitable position and allowed to remain until ankylosis in good position has been achieved.

Change of the Plaster Cast after Excision of the Femoral Head. If, after excision of the femoral head, one has applied the plaster cast with the limb in strong abduction so as to prevent pathological dislocation, one should correct this exaggerated position carefully in continuous traction after three to four months. Then a new thoracopelvic hip spica in which the affected limb is one to two cm. shorter is applied (see page 1098).

Prevention of Non-Union. In aseptic cases, nailing is the best treatment. But if the hip joint is infected one cannot use that method. The majority of infected cases result in necrosis of the femoral head, which in the roentgenograms shows relatively great density among atrophic surroundings (figs. 1662, 1668). As long as the head remains in the joint, the sinus will discharge. The entire hip region down to the middle of the thigh is usually swollen hard. Now and again retention of pus with high fever occurs. Therefore, it is best in every infection to excise the femoral head as soon as possible.

Treatment of Non-Union. In cases of only very mild, low-grade infection the wound may close soon and the head may escape necrosis. If one then applies a good plaster spica, bony union may even result. In case of non-union, however, the best treatment is pertrochanteric osteotomy (see page 1098).

Exercises. In both aseptic and infected cases the toes must be exercised actively from the first day on. In case of paralysis, a sling is applied to each toe and pulls it into slight hyperextension. In addition, a piece of sponge-rubber is placed between the sole of the plaster cast and the toes. It gives

elastic support to the toes, keeping them in slight dorsiflexion but allowing their active flexion against the resistance of the rubber

In aseptic cases the ankle joint is also exercised in the traction One should be very cautious in permitting motion of the hip lest inflammation might result

The limb should be exercised on the "mountain-climbing" apparatus (Vol I/figs 21, 22), at first for five minutes twice a day, then for an added 5 minutes per period each day up to 45 minutes twice a day *provided there is no pain*

Period of Immobilization In each infected gunshot wound of the hip joint one's aim should be ankylosis in good position, i e, in abduction and flexion of 10° to 15° each and in midrotation Good, pain-free walking for any considerable distance is possible only with the limb in this position If bony ankylosis is not complete, the hip joint will still be painful and there will be a tendency, even after years, to the development of a flexion and adduction deformity It is for this reason that the cast should be left for such a long time

Arthrodesis If bony union does not result, arthrodesis should be performed (fig 1565 e)

Further Treatment. Upon removal of the cast the mobility of the knee joint is greatly limited As a rule it increases rapidly if the knee is exercised on the knee flexion apparatus (figs 1574, 1575) twice a day, first for 5 minutes at a time and increasing each period by 5 minutes a day up to a total of 45 minutes twice each day *on the condition that there is no pain* To prevent swelling one should apply Unna's paste dressing extending from the webs of the toes to the knee (see page 1165) and put an elastic bandage round the knee As soon as the joint can be flexed to an angle of 120°, we begin with exercises on the "mountain-climbing" apparatus (Vol I/figs 21, 22) Thus there is increase in the mobility of the knee and ankle joints as well as in the strength of the muscles The muscles are strengthened most effectively by natural use, i e, by walking Warm baths and swimming are also helpful As soon as walking causes no pain, we start light athletics Handicraft may be begun while the patient is still in bed in the plaster cast and can be continued later in the occupational therapy workshop Energetic massage and forceful passive movements must not be used or allowed, since they may lead to a reappearance of infection even after many months

Exercises which cause pain must be forbidden (see Vol I/p 45)

Treatment of Gross Limitation of Flexion in the Knee Joint If permanent limitation of mobility in the knee joint results from persistent suppuration one can do a quadricepsplasty not earlier than six months after closure of the sinuses

Results of Gunshot Wounds of the Hip Joint

Mortality In the Franco-German War of 1870—71 the mortality rate was 79 7 per cent Eight (14 5%) of Jimeno Vidal's 55 cases died Happily, none of our nine cases died

Flail joints, pathologic dislocations and adduction contractures did not occur among Jimeno Vidal's cases nor among my own

Functional Results Among his 47 surviving cases, Jimeno Vidal had 16 with ankylosis and 22 with good mobility In 26 cases the knee was freely mobile Of my nine cases only four had ankylosis of the hip joint, four had good mobility and in one case mobility was limited The knee was freely mobile in three cases, while in six cases the function of the knee was limited The ankle joints and the feet were always freely mobile Drop-foot or pressure ulcer on the heel occurred neither among Jimeno Vidal's cases nor among my own

Questions We Should Ask Ourselves to Prevent Failures in Treating Infected Gunshot Wounds of the Hip Joint in Special Army Hospitals

1 Have I treated the "transportation shock" by supplying internal and external heat (hot drinks, warm blankets and baking) and good food?
2 Have I given blood when the patient's general condition indicated it (low blood-pressure, raised pulse rate)?
3 Have I allowed the transportation cast to remain if it fitted well, was free from lice and was not broken?
4 Have I allowed the patient to sleep after treatment of the shock, if no urgent operation was required owing to severe infection?
5 Have I made anteroposterior and lateral roentgenograms after the patient recovered from the rigors of transportation?
6 Have I left metal foreign bodies in noninfected cases?
7 Have I prepared a sufficient number of beds and traction appliances if the transportation casts were to be removed because of lice or because the casts did not fit well?
8 Have I given penicillin locally and generally while the patient was in the cast?
9 Have I given blood prior to operation in case of severe infection?
10 Have I removed the plaster cast in time in severe infections, and have I opened the joint widely from the posterior as well as from the anterior side?
11 Have I removed the fractured or crushed femoral head, splinters of the acetabulum and any visible metal splinters?
12 Have I refrained from any searching for metal splinters?
13 Have I chiseled off the caudal quarter of the femoral head to obtain good drainage if the femoral neck was preserved?
14 Have I exposed para-articular abscesses by wide incisions?
15 Have I placed a thick rubber drainage tube in the joint and fastened it with two wire sutures?
16 Have I placed the femoral neck in the acetabulum after having removed the femoral head?
17 Have I applied a thoracopelvic hip spica with the limb in strong abduction after having exposed the hip joint and all infected foci?
18 Have I cut suitable, quadrangular windows in the cast?
19. Have I prevented window edema by adequate compression?

20 Have I protected the cast well against wound secretion?
21 Have I exposed late-developing abscesses in time?
22 Have I stopped secondary hemorrhages by ligating the responsible vessels?
23. Have I severed the vessel before ligating it, if it was not torn completely through?
24 *Have I exposed and ligated the hypogastric artery if the bleeding vessel could not be located in the devitalized tissue?*
25 Have I refrained from secondary resection of the hip joint with excision of the acetabulum, since great new raw bone surfaces are thus created and because there results a great cavity which is prone to retain pus and from which suppuration may spread into the pelvis?
26 Have I prevented pathologic dislocations by strong abduction of the limb in the plaster cast or by a proper traction bandage?
27 Have I adducted the limb again in traction several weeks after excision of the femoral head and subsequent immobilization in abduction?
28 Have I, after having corrected excessive abduction, applied a plaster cast in which the injured limb was one to two cm shorter than the sound limb?
29 Have I seen to it that the patient began with active movements of the toes on the first day?
30 Have I, in case of paralysis, inserted a piece of sponge rubber under the toes and have I applied slings to the toes?
31 *Have I, if the patient was afebrile, seen to it that he began after one* week to exercise the sound limb on the "mountain-climbing" apparatus twice daily, starting with 5 minutes and increasing each period by 5 minutes each day up to 45 minutes twice daily, if it caused no pain?
32. Have I, if ankylosis was my aim, left the plaster cast on long enough, i e, for from eight to ten months?
33 Have I done an arthrodesis if bony ankylosis could not be achieved?
34 Have I kept the patient busy with handicrafts, etc, in bed and have I sent patients with "walking plasters" to the occupational therapy department?
35 Have I applied an Unna's paste boot from the webs of the toes to the knee and an elastic bandage round the knee after the plaster cast has been removed?
36 Has the patient exercised his knee on a knee-flexion apparatus?
37 *Have I protected the patient from massage and passive movements?*
38 *Have I seen to it that the patients never felt pain while they carried out the exercises?*

53. FRACTURES OF THE FEMUR

Classification The following fractures of the femur may occur

1 Intra-articular abduction or valgus fractures (figs. 1568, 1571);
2 Intra-articular adduction or varus fractures (figs 1569, 1572),
3 Separation of the proximal epiphysis of the femoral head (figs 1921, 1922),

4 Extra-articular fractures through the trochanteric region (figs 1570, 1573),
5 Isolated fractures of the greater trochanter (figs 1981, 1982),
6 Avulsion of the epiphysis of the lesser trochanter (fig 1983),
7 Fractures in the proximal third of the femoral shaft (figs 1984—1990),
8 Fractures in the middle third of the femoral shaft (figs 2001—2004),
9 Fractures in distal third of the femoral shaft (figs 2007—2013),
10 Separation of the distal epiphysis of the femur (figs 2061—2071),
11 Fractures of both condyles ("Y" or "T" fractures) (figs. 2029),
12 Unicondylar fractures (figs 2027, 2028, 2030—2037)

54. FRACTURES OF THE FEMORAL NECK

General Notes

Mechanism Fractures of the femoral neck are usually caused by falls on the hip (angulation fractures) or by quick turns of the body on a fixed lower extremity (torsion fractures) They may also occur if, for example, one inadvertently steps from sidewalk to roadway (shearing fractures) With tumor metastases, or after heavy irradiation of the pelvis, the femoral neck may break simply with walking or with turning over in bed These are of course pathological fractures Femoral neck fractures usually occur in elderly people whose bones contain reduced amounts of calcium salts, but they may also occur in younger people

Site of Fracture In most cases the fracture lies in the subcapital part of the femoral neck (figs 1568, 1569, 1571, 1583 to 1603), roughly at a right angle to the long axis of the femoral neck. In many cases the fracture line lies obliquely to the long axis of the neck, i e , more or less parallel to the long axis of the body (figs 1712, 1714, 1728, 1729) Fractures through the trochanteric region (i e , pertrochanteric fractures) must be distinguished from femoral neck fractures, since they usually require different treatment and since prospects of recovery are quite different in the two groups

Types of Fractures and Displacements of Fragments The **abduction or valgus fracture** is the less frequent type, occurring in about ten per cent of the cases (figs 1568, 1571, 1583—1593) It always shows a coxa valga and usually no external rotation of the leg There is angulation between the *tightly impacted* fragments, the angle being open superiorly and laterally Bony union always occurs, even without treatment I have never seen this type of fracture in a patient under forty years of age

The **adduction or varus fracture** (figs 1569, 1572, 1564—1603) with coxa vara and external rotation of the extremity is much more frequent, occurring in about 90 per cent of the cases The angle formed by the two fragments is usually open caudally and medially (fig. 1594) and dorsally (fig 1596) As a rule this fracture is *not impacted,* and if it is not reduced accurately and immobilized in good position long enough, i e , until bony union has occurred, it usually goes on to non-union with permanent impairment of the extremity's function

Complications Following Femoral Neck Fractures The fracture of the femoral neck is the most serious of all closed extremity fractures Its most common result used to be non-union, or pseudarthrosis In fact, fifty years ago there was question as to whether bony union was possible at all It has, however, in the last few decades been shown that even these fractures generally go on to bony union if they are properly treated (see end results, page 1230) The most frequent complication at present is avascular necrosis of the femoral head, which even with operative treatment occurs in 20—30 per cent of all cases Necrosis of the femoral head and non-union are often accompanied by more or less severe contractures, the hip and knee being flexed and the extremity being adducted and externally rotated (figs 1810—1813). The gait is limping, and walking is painful

Avoiding Complications Following Femoral Neck Fractures Pseudarthrosis can nearly always be avoided by accurate reduction and uninterrupted immobilization for a sufficiently long time This can best be achieved by means of a three-flanged nail or a screw Avascular necrosis of the femoral head, on the other hand, is as a rule the result of primary vascular damage and is less frequently due to technical errors or to damage from inserted metal

Clinical Examination in Cases of Suspected Fracture of the Femoral Neck. Routine examination is conducted as described on pages 1073 and 1074 It will be noted that shock is relatively mild as compared with that seen in dislocation of the hip

Fractures of the femoral neck are often overlooked and are wrongly diagnosed as simple contusions Femoral neck fracture should, however, be suspected in any *elderly* patient who is unable to get up again after a fall

In adduction or varus fracture the local examination usually shows external rotation *deformity* of the involved lower extremity amounting to 45° to 60°, whereas in pertrochanteric fractures the extremity is as a rule nearly 90° externally rotated so that the lateral side of the foot lies on the bed When the fracture is a few days old, however, even the adduction or varus fracture may show external rotation approaching 90° As a rule, impacted abduction or valgus fracture does not result in rotation deformity

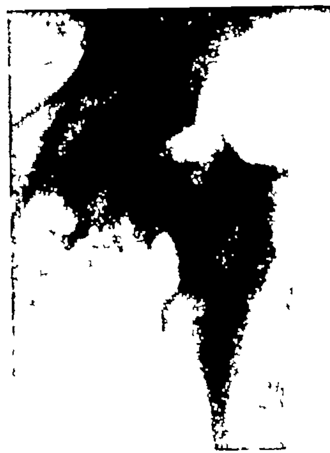
In the medial fractures of the femoral neck neither *swelling* nor *discoloration* due to hematoma develops, while in pertrochanteric fractures both usually appear after a few days If a hematoma be found accompanying a medial fracture of the femoral neck, it is due not to the fracture itself but to contusion of soft tissue

With neither an adduction varus fracture nor a pertrochanteric fracture is the patient able to lift the extended limb from the bed, whereas often the patient with an impacted abduction fracture is able to do that Many patients with femoral neck fracture are, however, able to flex the affected hip joint and the knee joint if the heel is allowed to slide along on the bed

As a rule, adduction or varus fractures result in a *shortening* of one to three centimeters, which is not the case with abduction or valgus fractures The patient with an adduction or varus fracture complains of local tenderness and usually feels pain when pressure is applied to the heel in the long axis of the limb *(impingement pain)* as well as when traction is applied to it Pain is

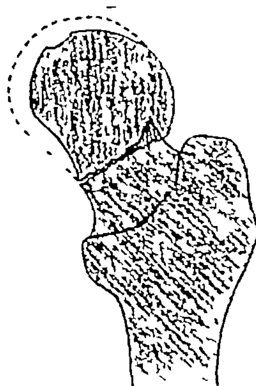
also felt when the limb is rotated either with the hip joint extended or, more particularly, with it in right-angle flexion

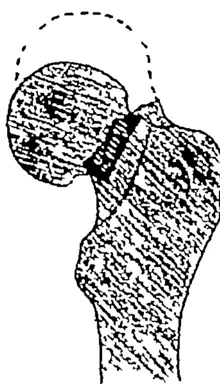


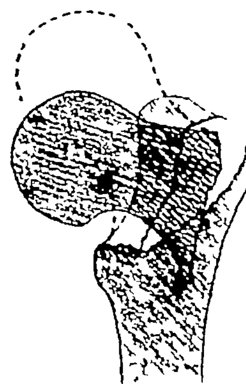




1568 1569 1570







1571 1572 1573

FIG 1568—Medial, subcapital, intracapsular fracture of the femoral neck with abduction or valgus position As a rule, such a fracture is firmly impacted The fragments form an angle open laterally Angulation of the distal fragment in the coronal plane is slight, and therefore the fovea centralis of the femoral head is visible The femoral head is tilted out of the acetabulum laterally The trabeculae no longer parallel the axis of the femoral neck but are vertical The limb is rotated internally, so the lesser trochanter appears small and the crista intertrochanterica is superimposed upon the base of the femoral neck (see figure 1571)

FIG 1569—Medial, subcapital intracapsular fracture of the femoral neck with adduction or varus position The fragments are usually loose in this fracture and not impacted The angle formed by the fragments is open not only inwards (medially) but also backwards (dorsally) (see figure 1596) The fovea centralis is not visible because the medial part of the femoral head is angulated backwards (dorsally) The femoral head is tilted down out of the acetabulum (caudally) The limb is rotated externally, so the lesser trochanter appears big and the crista intertrochanterica is superimposed on the the femoral neck (see figure 1572)

FIG 1570—Pertrochanteric, completely extracapsular fracture of the femur It is wrong to call this type a fracture of the femoral neck This fracture is often impacted, but not stable The fragments form an angle open inwards (medially) and backwards (dorsally) The limb shows strong external rotation, so the lesser trochanter appears big and the crista intertrochanterica overlies the femoral neck (see figure 1572)

FIGS 1571—1573—Sketches re figures 1568—1570

In fractures of the femoral neck there is no evidence of *crepitation* or *abnormal mobility*, and injuries to *nerves* and large *vessels* do not occur

In cases of valgus fracture, walking is sometimes possible Pain on torsion may be the only symptom of these fractures

Roentgen examination should follow the clinical examination in every case in which femoral neck fracture is suspected Local anesthesia should be given by injecting 20 cc of a 2% Novocain solution into the joint before the roentgenograms are made in order that the limb can be moved about as necessary without causing the patient pain Three roentgenograms should always be made the first in the A-P projection with the limb in the pathologic position of external rotation (figs 1584, 1704), the second also in the A-P projection but with the limb in internal rotation (figs 1583, 1706), and the third either from the medial side with the tube aimed craniolaterally and with the affected limb internally rotated and abducted (fig 1705), or in the A-P projection with the patient in the lithotomy position (figs 1585, 1596) Roentgenograms taken in this lithotomy ("frog") position also afford good comparison with the sound side In case the findings are questionable, an A-P scout film of the entire pelvis should also be made.

Questions We Should Ask Ourselves in Order to Avoid Mistakes in Cases of Suspected Fracture of the Femoral Neck

A General Questions these are the same as in dislocation of the hip (see page 1088)

B Specific questions concerning fracture of the femoral neck·

1 Have I asked how the accident happened (was there a fall on the hip)?
2 Have I asked whether the patient could walk after the accident?
3 Have I looked for deformity (external rotation)?
4 Have I looked for discoloration (hematoma)?
5 Have I asked the patient to raise the extended limb from its support?
6 Have I determined whether the patient is able to flex the hip and knee with the heel supported?
7 Have I measured the length of each leg and compared the two?
8 Have I examined for hip pain on traction, on impingement (pressure applied to the heel in the long axis of the limb), on torsion and on local pressure?
9 Have I given local anesthesia before the roentgen examination?
10 Have I made roentgenograms with the limb in external and internal rotation and from the medial side or with the patient in the lithotomy position?

TREATMENT OF IMPACTED ABDUCTION OR VALGUS FRACTURES OF THE FEMORAL NECK

No reduction is necessary in this type of fracture, since the relatively mild valgus position has no ill effects Indeed, reduction should be avoided, since fragments may thereby be disturbed and previously-preserved vessels may be torn with the development of aseptic necrosis of the femoral head as a possible result Moreover, a separated head of the femur takes 6 to 12 months

to unite if treated with nail, screw or Whitman plaster And otherwise pseudarthrosis usually develops In contrast, bony union always occurs in impacted abduction or valgus fractures within 6 to 8 weeks (figs 1586—1588)

Immobilization Formerly we applied a short, non-weightbearing plaster hip spica (fig 1678, 1679) for 10 to 12 weeks and then later shortened the time to 6 to 8 weeks Since 1944 we have not used those immobilizing casts, despite which we have never seen a firmly impacted femoral head come loose It suffices to support the limb on a pillow or on a well-prepared Braun splint for one to three weeks

Exercises From the first day, the toes and the subtalar and tibiotalar joints are moved through their full ranges of motion After a week the



1574 1575

FIGS 1574, 1575 —Exercise on the knee flexion apparatus A padded sling cradles the ankle A strong hemp cord with a handle is fastened to it The knee joint is extended by pulling the cord In order to strengthen the muscles, the patient should try to raise his leg actively and only help himself a little by pulling After a few days he is able to extend the knee without pulling the cord Flexion of the knee is increased by raising the cross-bar If flexion cannot be achieved in this way, a sandbag can be put on the ankle The exercises should be started with twice five minutes daily and extended by five minutes per session per day up to twice forty-five minutes daily, if no pain is felt

patient extends and flexes the knee joint using the knee-flexion apparatus (figs 1574, 1575) for five minutes each morning and five minutes each afternoon If these exercises cause no pain, each session is lengthened five minutes daily up to a total of 45 minutes twice a day

Application of Unna's Paste Dressing to Foot and Leg and of an Elastic Bandage about the Knee Joint After one to three weeks, if movements in the hip joint do not cause significant pain, an Unna's paste dressing is applied and the patient is allowed up During the day an elastic bandage is put round the patient's knee

Duration of Treatment In these fractures bony union usually occurs after six to eight weeks (figs 1586—1588)

Necrosis of the Femoral Head After Impacted Abduction or Valgus Fractures Necrosis usually appears as late as one or two years after the

accident Patients who have had no earlier complaints then occasionally feel dragging pain in the knee and later on in the hip joint as well, the pain increasing from year to year At first it is felt only with weight-bearing but later it is felt also at rest or when turning over in bed Mobility of the hip is reduced and the typical flexion and external rotation contracture develops (figs 1810—1813) Usually the complaints are explained as being of rheumatic nature Roentgenograms show the real cause of the trouble, viz, collapse of the femoral head (figs 1589—1593)

Causes of Necrosis of the Femoral Head after Impacted Abduction or Valgus Fractures Of 40 cases examined 3 to 23 years after the accidents, necrosis occurred in only five cases (12 5%) We formerly thought it might be due to the valgus position and that weight-bearing could be injurious to those trabeculae which are in a vertical position, as shown in figures 1568 and 1571. If that were the case, however, it would occur more frequently Probably it is the result of primary damage to the vessels caused at the moment of injury Most, and the largest, vessels enter the femoral head at the epiphyseal region (figs 1564 g and h) If the vessels lie close under the surface they may be torn or wedged-in and contused by displacement of the fragments and become thrombosed. The upper part of the femoral head is thus cut off from its blood supply and collapses under weight-bearing after one to two years, as shown in the roentgenograms of figures 1590—1593

Avoidance of Necrosis and Collapse of the Femoral Head after Impacted Abduction or Valgus Fractures The suggestion that this fracture should be reduced in order to set free any compressed vessels must be rejected, since necrosis of the head occurs in only 12 5 per cent of impacted fractures of the femoral neck as against 30 to 35 per cent in nonimpacted fractures of the neck The danger of necrosis of the femoral head would seem, then, to be increased by separating the impacted fragments Even were this not so, one cannot know beforehand in which cases necrosis will develop There is no means of finding out whether the vessels have been torn or only wedged-in between the fragments and compressed If they are torn, reduction is useless, and if they have been wedged-in for some time they are likely thrombosed and their lumina obliterated

The suggestion that early weight-bearing in all impacted fractures of the femoral neck should be avoided must also be rejected, again as necrosis of the femoral head develops in only 12 5 per cent of the cases and because one does not know beforehand in which cases that will happen But every patient should be told to present himself again for examination should he later feel pain after having had no complaints for one or two years

Treatment of Necrosis of the Femoral Head After Impacted Abduction or Valgus Fractures of the Femoral Neck If the necrosis of the femoral head is recognized early and the head shows only the first signs of collapse, one might on theoretic grounds try to prevent further depression by using a weightbearing brace, a short plaster spica with a long walking caliper (figs 1678, 1679), or

simply by using crutches Frequently revascularization of the femoral head can be achieved in this way in femoral neck fractures in adolescents and in Perthes' disease of the hip joint Success of this method in adults is very doubtful

If the head of the femur has already disintegrated and severe pain and contractures have developed, the most successful treatment is arthrodesis (fig 1565 e) or arthroplasty (fig 1565 b) of the hip joint Since 1949 we have been using Judet femoral head prostheses

Inappropriate Treatment of Impacted Abduction or Valgus Fractures of the Neck of the Femur

Application of a big plaster spica (thoracopelvic hip spica) (figs 1627 until 1640) for six months, as in adduction or varus fractures, is unnecessary because there is no danger of displacement of fragments and because these fractures usually unite within six to eight weeks even without immobilization The big plaster spica would be only an unnecessary burden to the patient

Our experience since 1944 has shown it to be unnecessary to apply even a short plaster spica

Extension treatment is likewise superfluous, as the limb is not shortened and the fragments are firmly impacted

Nailing an impacted *abduction or valgus fracture* is not only superfluous but may even be dangerous, as further vessels become torn at the operation and because the use of magnetic oxydizeable material may lead to rust-granulomata and to collapse of the femoral head We have seen such cases

Questions We Should Ask Ourselves to Avoid Failures in Treating Impacted Abduction or Valgus Fractures of the Femoral Neck

1 Have I determined whether rotation is painful?
2 Have I made anteroposterior roentgenograms with the limb in outward and inward rotation as well as a mediolateral view?
3 Have I not applied a big plaster spica?
4 Have I not applied a short plaster spica?
5 Have I not applied extension?
6 Have I not performed reduction and internal fixation with a three-flanged nail or a screw?
7 Have I placed the leg on a pillow for one to three weeks?
8 Have I had the patient move his toes and his subtalar and talotibial joints through their full ranges from the first day?
9 Have I had the patient begin in the second week to exercise on the knee-flexion apparatus, starting with five minutes each morning and five minutes each afternoon and increasing each session by five minutes daily up to a total of 45 minutes twice a day, if it caused him no pain?
10 Have I applied an Unna's paste boot from the toes to the knee and an elastic bandage round the knee after one to three weeks?
11 Have I allowed the patient up after one to three weeks if he felt no pain?

The Short Weight-Bearing Plaster Hip Spica

Formerly we applied a short plaster spica in impacted abduction or valgus fractures of the neck of the femur Now we use it, together with a long weight-bearing walking caliper, only for some fractures of the femoral neck in young people (figs 1874—1899) and in Legg-Calvé-Perthes disease of the hip

The things needed for *application of a short plaster spica* are almost the same as those needed for a thoracopelvic hip spica (see page 1214)

Position of the Patient for Application of a Short Plaster Spica After the ankles and feet have been well padded, the footslings are put on First the 20×30 cm pad is put on the pelvic support, then the patient is placed on it

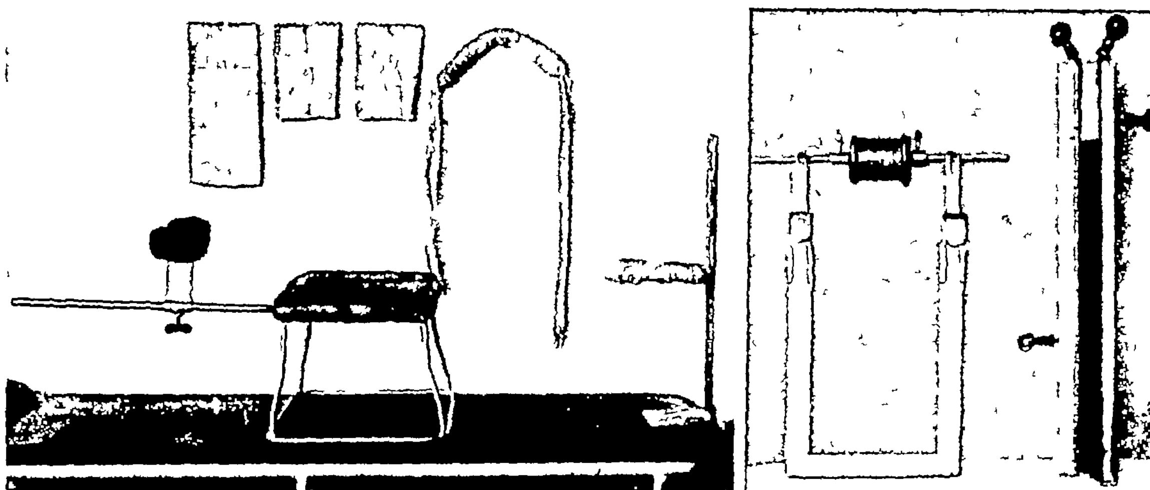


Fig 1576—Pelvic support and bench for back and head The pads for the plaster hip spica are hanging on the wall — the big one for the sacrum, the two small ones for the anterior superior iliac spines and the iliac crests, and the tuberosity pad The pads should not exceed a thumb's thickness The picture on the right shows pulleys which can be fixed to the bed

His upper back and head rest on the small bench with the head-support Both feet are fixed to the foot-plates The limbs are abducted only so far that the distance between the two heels is 25 to 30 cm The inner sides of both feet should be in an exactly vertical position, i. e, in mid-position between internal and external rotation (fig 1577)

If no such extension apparatus is at hand, the lower limbs are placed on adjustable instrument tables (fig 1627) A roll of cellulose wadding or of sponge rubber is put under each heel (fig 1634) to avoid pain from pressure An assistant then holds each lower limb while the plaster bandages are applied Traction on the limbs should be avoided

Application of the Pads After arranging the patient, one paints the regions of the anterior superior iliac spines with a skin adherent (Mastisol) The 18×10×0 15 cm pads are then put on in such a way that they protect mainly

the caudal aspects of the spines and the crests of the ilium The roll of cotton-wool is put round the inner side of the thigh and particularly under the ischial tuberosity, the two ends of the roll being tied under the axilla of the injured side and above the shoulder of the sound side The 15×15 cm jaconet is put over the pubic hair so that it is not incorporated in the plaster With six to eight six-inch-long strokes of a large swab, the skin of the involved thigh proximal to the knee is painted with skin adherent (e. g Mastisol) Then the flannel strip 40 to 50 cm long is wrapped round that thigh and is loosely fixed by a gauze bandage The pads are fixed with the 15 cm broad bandage

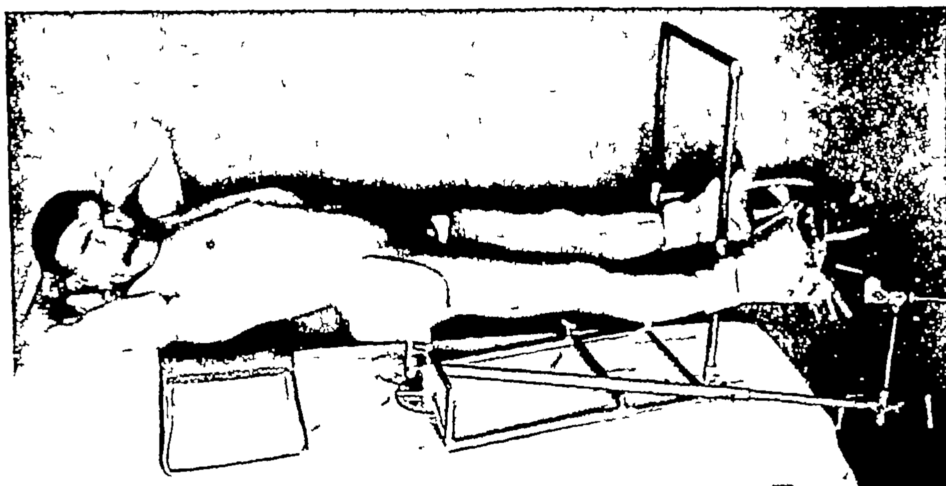


Fig 1577 —Position of the patient on a screw-traction apparatus for the application of a short weight-bearing plaster hip spica The patient is lying on the pelvic support and the thoracic bench with the head support Both ankles are fixed to the screws with slings The sole of the "sick-side" foot is fixed against the iron foot-plate For application of a short plaster hip spica the foot must be in mid-position between internal and external rotation The distance between the heels is 30 cm At present we also fix the sound-side foot to a foot-plate

Application of the Plaster Spica After the padding, three plaster bandages 20 cm broad are wound round the pelvis and thigh down to the knee At the same time, three plaster slabs are made from three plaster bandages on a smooth, hard-topped (e g , glass-top) table, each measuring 1 meter in length Two of them are put round the pelvis in such a way that the first runs from the anterior superior iliac spine of the sound side over the greater trochanter of the sound side to the sacrum, thence to the greater trochanter of the injured side and on to the anteromedial side of that thigh The second slab is put on the abdomen and carried over the greater trochanter of the injured side to the posteromedial aspect of the thigh The third slab is cut into three equally long pieces The first piece is put on the lateral side of the hip joint in the direction of the long axis of the body, the second piece is put on the anterior side and the third on the posterior side of the hip joint caudally enough to

cover the buttock (figs 1578—1580) Depending on the size of the patient, two to four circular plaster bandages are then applied round the pelvis and thigh The ischial tuberosity pad should be covered with the last plaster bandage which must not, however, touch the skin Also at the knee, care should be taken that the plaster ends one or two centimeters above the lower margin of the flannel The lower margin of the flannel is then incised, turned up and fixed with plaster to the end of the cast

Molding the Plaster Cast Molding of the cast to the body starts with the application of the plaster bandages Molding is particularly important above



1578 1579 1580

FIG 1578—Back view of a badly trimmed plaster hip spica The ischial tuberosity has no support, the buttock bulges out over the edge of the cast, and blisters and pressure sores may be the result

FIG 1579—To improve the faulty plaster cast, an ointment dressing is tucked under its edges, the ischial tuberosity is padded with a roll of cotton-wool, and the gap in the cast is closed with a plaster slab

FIG 1580—A properly-trimmed plaster hip spica The plaster ends two fingers' breadth from the fold of the buttock The support for the ischium is clearly visible (Pictures from our collection originally published by Schneck)

and below the crests of the ilia, round the greater trochanter and the ischial tuberosity A horseshoe-shaped depression should surround the trochanter, with its open side directed dorsally beneath the ischial tuberosity (figs 2081, 2082) The plaster should not be molded about the femoral condyles, since otherwise pain from pressure will develop there

Trimming the Plaster Cast When the plaster has set, the edges of the cast are trimmed with a sharp knife so that they do not touch the ribs ventrally or laterally and so that the umbilicus lies free Flexion of the sound hip to a right angle must be possible, since otherwise the patient will be unable to sit comfortably When the cast is trimmed, the ends of the tuberosity pad are out a hand's breadth above the plaster spica They are then turned down and fixed with adhesive tape Then the patient is turned into the prone position The plaster spica must not end with a sharp edge at the ischial tuberosity but must form a small seat under the tuberosity pad At the buttock the cast may be cut out only so far that it ends one or two finger-

breadths lateral to the intergluteal fold If more is cut away the buttock will bulge out at the edge of the plaster and blisters and pressure sores will develop If these troubles have already developed, an ointment dressing is put on and a plaster slab is put over it to cover the buttock properly, and then the slab is fixed with a circular plaster bandage (figs 1578—1580). In the popliteal fossa the plaster cast is cut away so far that the knee can be flexed beyond the right angle Sharp edges are bent outward with a cast-opener



1581, 1582

Figs 1581, 1582—Weight-bearing plaster hip spica for beginning necrosis of the femoral head to avoid a depression of the head This short plaster spica with the long weight-bearing caliper must be continuously worn for one or two years until roentgenograms show that the calcium content of the femoral head is normal again Compare with fracture of the carpal scaphoid, shown in Vol I/figs 306—311 A higher heel must be put on the shoe of the sound side This weight-bearing plaster spica is used only in young people

Application of the Weight-Bearing Caliper (figs 1678, 1679) The caliper should be so long that the heel is four or five cm above ground at weight-bearing At least every four or five weeks it should be checked to make sure that it really is weight-bearing

Drying the Plaster Cast, Smoothing its Edges and Putting On Braces The plaster cast sets after ten minutes, but it takes 24 hours or more to dry To speed up drying, a baker is used for some hours On the following day the two ends of the tuberosity pad are pulled tight and fixed with a small slab of plaster or Cellona When the patient walks the plaster cast slides down one or two cm because of its weight and may cause pressure above the knee To avoid that, felt-padded web-strap suspenders with buckles for adjustment

are applied To attach them, slits may be cut in the plaster about a hand's breadth below the upper edge of the plaster in front and in back and the suspenders threaded through At present we fix hooks to the ends of the suspenders and catch them round the lower edge of the pelvic part of the



1583, September 10, 1935



1584, September 10, 1935,



1585, September 10, 1935

Fig 1583—Impacted medial subcapital intracapsular abduction or valgus fracture of the femoral neck in a 67 year old woman, caused by a fall The fracture gaps medially, the femoral neck is impacted deep in the lateral part of the head The angle formed by the fragments is open laterally (valgus or X-position, compare figures 1568, 1571)

Fig 1584—Comparison picture re figure 1583 in forced external rotation of the limb The medial fracture gap is better shown

Fig 1585—Comparison picture re figures 1583 and 1584 in lithotomy position to allow comparison with the sound side The fracture gaps anteriorly and is slightly impacted posteriorly This picture has been photographically diminished in size slightly more than have the A-P views

plaster. The edges of the plaster should be smoothed with a plaster knife and covered with adhesive-tape or a Cellona bandage (figs 1581, 1582)

Marking the Plaster Cast The prereduction roentgen findings are sketched on the plaster at the level of the fracture The date of the injury, the date

of application of the plaster cast, the date of its intended removal and the name of the surgeon are inscribed (fig 1581)



1586, November 27, 1935



1587, November 27, 1935



1588 November 27, 1935

FIGS 1586—1588—Check roentgenogram re figures 1583—1585, after eleven weeks This woman was allowed up in a short plaster hip spica three days after the injury The plaster was removed after seven weeks Since 1944 we have not used a plaster spica The fracture has united in a slight valgus position The femoral neck is slightly shortened The fracture gap is bridged All three views show that sound bony union has been achieved

TREATMENT OF ADDUCTION OR VARUS FRACTURES OF THE NECK OF THE FEMUR

General

Whereas the treatment of impacted abduction fractures with valgus position of the fragments (figs 1568, 1571, 1583—1593) is quite simple, the treatment of adduction fractures with varus position of the fragments is difficult

Prognosis in the subcapital medial adduction or varus fracture of the femoral neck is bad because rather large numbers of vessels in the epiphyseal

region (figs 1564 g and h) are always torn or compressed by displacement of the fragments The vessels which are compressed but not torn can be freed and made pervious again by early and exact reduction And, if there is then uninterrupted immobilization of the head and neck for a sufficiently long time, bony union in good position can usually be achieved even in these fractures But good function of the limb cannot always be achieved, since complete necrosis of the femoral head develops in 15 to 17 per cent of these cases, partial necrosis of the head develops in another 15 to 17 per cent, and arthrosis develops in some others. Thus only two-thirds of all fractures of the femoral neck heal and allow full use of the limb



1589, April 15, 1931 1590, November 21, 1934, 1591, November 30, 1937

FIG 1589—Impacted abduction fracture of the femoral neck with valgus or X-position in a 59 year old man, caused by a fall

FIG 1590—Check roentgenogram re figure 1589, three and a half years later The site of the fracture is no longer visible *The femoral head has partially collapsed, causing its calcification to appear increased and irregular*

FIG 1591—Check roentgenogram re figure 1589, six and a half years later The femoral head has collapsed still further Calcification has become more irregular

In fracture of the femoral neck as in fracture of the carpal scaphoid (Vol I/figs 302—311), new vessels grow from the distal fragment into the proximal fragment if reduction is good and *immobilization* is uninterrupted. But it takes usually six months or more before bony union develops While complete and uninterrupted immobilization of the fragments in fracture of the carpal scaphoid for such a period is relatively simple, complete and uninterrupted immobilization in fracture of the femoral neck is extremely difficult

At present three methods are used for immobilization of the fragments after accurate reduction

1 Continuous traction with pin or wire, or with adhesive tape or Unna's paste dressing,

2 The plaster spica from axillae to the tips of the toes with the limb extended in strong abduction and internal rotation, as used by Whitman, Lorenz and Lofberg, or

3 Internal fixation of the fragments with the three-flanged nail of Smith-Petersen and Sven Johansson, or with screws or strong pins



1592, November 21, 1934



1593, November 30, 1937

FIG 1592 —Comparison picture re figure 1590 in lithotomy position, three and a half years after the injury The femoral head has collapsed, the femoral neck is shortened A triangular sequestrum has broken out in the region of the ligamentum teres A jagged fracture line is visible below the epiphyseal line Cranial and caudal marginal exostoses Broad joint space Therefore flexion is almost free, rotation and abduction severely limited. Pain on walking

FIG 1593 —Comparison picture re figure 1591 in lithotomy position, six and a half years after the injury Further crushing of the femoral head The jagged fracture line is no longer visible The triangular sequestrum has separated The marginal exostoses have become bigger Motion has diminished, pain has increased

Since fractures of the neck of the femur frequently occur in elderly people in poor general condition, the big plaster spica or internal fixation cannot always be used In these patients continuous traction is the appropriate method Though it is very difficult to achieve bony union by this method (figs 1615—1625), treatment is facilitated by it especially during the first few days At present we use the three-flanged nail for most femoral neck fractures if patients appear fit for operation

TREATMENT OF FRACTURES OF THE FEMUR BY CONTINUOUS TRACTION WITH NAIL OR WIRE

General

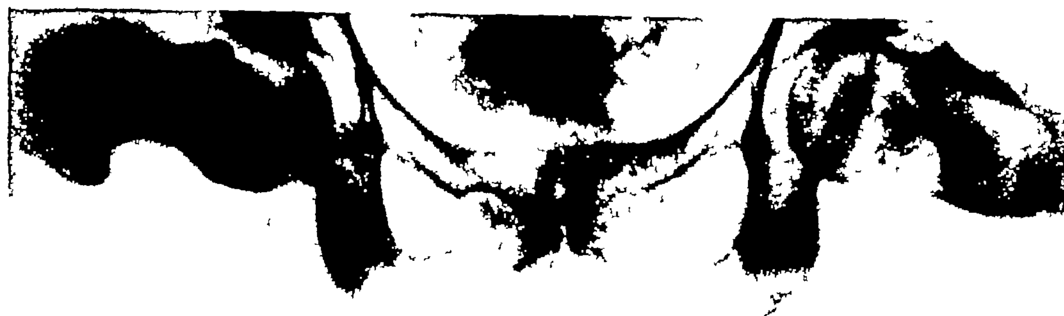
Every fracture is followed by devitalization and absorption of from one to three millimeters of bone from the end of each fragment. Opportunity must be given the fragments to come together and make up for this bone



1594



1595



1596

FIG 1594—Medial adduction or varus fracture of the femoral neck with pronounced external rotation of the femoral shaft The femoral neck appears markedly shortened and the lesser trochanter large because of the external rotation The femoral neck is displaced upward lateral to the head with shortening of the limb

FIG 1595—Comparison picture of figure 1594 with the limb in internal rotation The femoral neck appears longer and the lesser trochanter smaller Lateral displacement and shortening appear less pronounced

FIG 1596—Comparison picture of figures 1594 and 1595 in lithotomy position A comparison with the sound side clearly shows shortening, angulation with an angle open dorsally, and lateral displacement

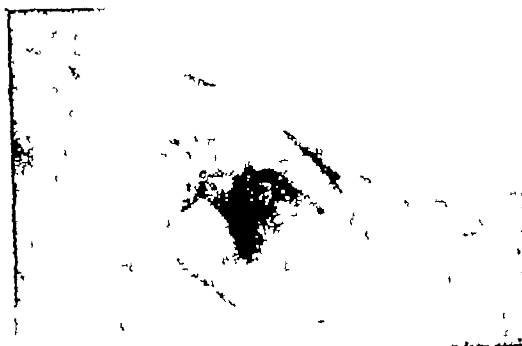
loss. Therefore, the aim of treatment of every fracture should be to produce a shortening of from one to ten millimeters and under no circumstances to produce a lenghtening. This may sound surprising, since until now we have always been urged to avoid any shortening The amount of shortening for which we should, in fact, strive is as a rule not more than one centimeter

The disastrous effects of lengthening in fractures are described in Vol I/pp 25—27 and in M N pp 98—127

The goal in treatment of fractures of the femur, as with the goal in treatment of other fractures, should be bony union without remarkable



1597



1598



1599



1600

FIG 1597 —Check roentgenogram re figures 1594 and 1595, after continuous traction with 7 Kg for 24 hours The lateral displacement has disappeared and with it the shortening The trabeculae of the femoral neck are not in alignment with those of the head — a sign of angulation

FIG 1589 —Comparison picture re figure 1597, medial view There is still an angle open dorsally Ventrally the fracture gap is wide

FIG 1599 —Check roentgenogram re figure 1597, after traction for another 24 hours with 10 Kg and stronger internal rotation The traction weight of 10 Kg was too heavy, so the femoral neck is now displaced caudally, whereas it had been displaced cranially in figure 1594 and was in the correct position in figure 1597 Increased internal rotation of the limb would have been sufficient without increasing the weight of traction The lesser trochanter appears small because of internal rotation The femoral neck is visible in its full length

FIG 1600 —Comparison picture re figure 1599, lateral view The angle open dorsally has disappeared The fracture is well reduced

shortening, without rotation or angulation, without decalcification of bones or atrophy of muscles and without circulatory disturbances, but with full mobility of all joints As many statistics show, this goal is not always achieved [1] The basis for a great many poor results in fracture treatment is the **exaggerated importance accorded lateral displacement**, particularly in transverse fractures, and the use of **excessive continuous traction** in attempting to overcome it This causes gaping of the fragments, or diastasis, and prevents the approximation of those fragments essential to early callus formation It leads, moreover, to vascular spasm and diminished blood-supply and consequently to



1601 January 19, 1953 1602

Figs 1601, 1602—Impacted medial adduction or varus fracture with strong upward (cranial) displacement The calcar femorale is firmly impacted in the femoral head Impaction in varus fractures is only possible in those in Pauwels' group III The medial view shows marked anterior angulation

disturbed callus formation, to pseudarthrosis, refractures, swelling, atrophy of muscles, decalcification of bone, shrinking of ligaments, impaired joint movement, etc

Laymen are deeply impressed by lateral displacement So, unfortunately, are many surgeons, and they try to overcome it at whatever cost As a rule that can be done only by pulling the fragments apart, so that there is lengthening, at which time it is easy to reduce the lateral displacement If the traction is then diminished, the fragments again come together But if one then allows this excessive traction to continue, one has not "corrected" or "reduced" but has rather changed a harmless lateral displacement into a dangerous longitudinal displacement with lengthening (dislocatio ad longitudinem cum distractione aut elongatione)

[1] Bohler, L Behandlungsergebnisse der Oberschenkelbruche, Arch f orthop u Unfall-Chir 35 466–510, 1935

It is far too little appreciated that lateral displacement amounting to half the breadth of the shaft in fractures of the leg and the forearm and amounting to the entire breadth of the shaft in fractures of the femur and humerus are functionally and cosmetically harmless provided there is no rotation, angulation or remarkable shortening (Vol I/figs 261—268, 271—293, Vol II/figs 2016 until 2026) On the other hand, M N/figs 322—376 show the disastrous results of excessive continuous traction Most surgeons pay little attention to this dangerous longitudinal displacement with diastasis of the fragments, even when it is so marked as shown in M N/figs 344 and 345. To avoid such



1603 January 28, 1953 1603 a

Figs 1603, 1603 a—Check roentgenogram re figures 1601, 1602 The impacted fragments separated only after nine days of continuous traction when the traction weight had been increased to 12 Kg, causing an 8 mm diastasis in the hip joint The position of the fragments here is ideal in both projections, so the fracture was nailed

damage, accurate determination of the weights to be used in continuous traction is essential

Accurate Determination of the Weights as the Crucial Problem in Continuous Traction Treatment of Fractures

As continuous traction causing a gaping of fragments and lengthening of the broken bone leads to the damages described above, the weights used in each case must be determined accurately and must be frequently checked Weights of as much as 10 to 20 Kg, as suggested in many textbooks, are far too large Such weights are sometimes shown in rough sketches, sometimes in photographs The photographs, which give the more truthful picture, often show such things as a sand-bag and a kitchen-scale weight hanging together with the weight from an old grandfather's clock, and no one is able to tell the actual weight of the traction

That the amounts of weight used in traction are not always accorded the attention they deserve is strikingly emphasized by Kirschner [1] "It is important that the surgeon be able to recognize *the total weight with one look* The sandbags so often used seldom allow that Frequently very porous, loosely-woven cloth is used to hold the sand, and often the weight of the sand is unknown Even more unpleasant pictures are those of sand-filled buckets, old food tins or gasoline cans — things often used, incidentally, as ashtrays and waste paper baskets by those patients who are up and about Actually, almost any significantly heavy thing may be found serving as a traction weight, from things that could be better used for other purposes, e g , tools, or the costly parts of other traction appliances, to the bases of old dismantled lamps and pieces of rusty scrap-iron If one asks the *total weight* of such motley collections of metal, there follows much busy counting and calculating with ultimate arrival at widely varied results "

Weights used in continuous traction must be very carefully administered, just as with a poisonous drug A simile might also be drawn from the use of table salt. if too little is used, more can be added; if too much is used, the dish is spoiled forever Since 1920 we have been using weights as shown in figures 118, 621—626, 1604 a—1606 and 1611 An iron disc is fixed to an iron rod the top end of which is bent into a hook This whole "carrier" weighs one Kg If required, it can carry from one to four additional standard slotted weights of one Kg. each

In order that the number of these one-Kg weights can easily be counted at any time, not more than four (making, with the carrier, five Kg total) should be hung on any one carrier If one then needs, for example, eight Kg , one should have a total weight of five Kg in one carrier-unit and three in another (fig 1605) rather than four Kg in each of two units

One should never use weights of varied size — e g , 1 Kg , 2 Kg , 2 5 Kg , 3 Kg , etc — because reading and calculating the total weight takes then too much time and is therefore as a rule neglected

In order that traction can be increased or decreased by a simple movement of the hand, the weights should be hung on carriers and not tied on with ropes Untying knots (or, incidentally, pulling off large pieces of adhesive-tape from weights otherwise properly hung on carriers) takes too much time and is therefore often neglected If one orders that weights be changed but does not wait to see it done, one often finds on his next rounds that the order has not been carried out If the weights are put on carriers, and are not too firmly plastered down with adhesive tape, they can be changed easily during the rounds without loss of time

Many surgeons are entirely disinterested in traction weights despite the fact that those weights are the most important things in continuous-traction treatment Some surgeons have told me that they never bother about traction weights in their patients, that it is entirely up to the nurses to take care of them. Moreover, it is often true that hospital administrators object to the

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[1] Kirschner, M Randbemerkungen zur Kriegschirurgie in den Heimatlazaretten, Berlin, OKW Press, 1942, p 38

purchase of standard weights, although they are not expensive and will last for decades and even centuries if they are properly treated I have often seen hospitals newly built or for which all equipment was ordered new — except the traction weights Only that rusty assembly, varied in size and in shape, was carried over into the new building During the war it was impossible to get standard weights introduced despite my repeated requests from the very beginning of the war and despite Kirschner's paper (see page 1180)

The fate of a fractured bone and therefore the fate of the patient depend upon the choice of the proper traction weight Experience shows that one-seventh of the body weight is required in strong, muscular people — e g, weights of 10 Kg for patients weighing 70 Kg — if the arrangement of the patient is as described below and if traction is applied through the tibial tubercle In compound fractures the weight must be less

As a rule, only one-tenth of the body weight should be used in compound fractures and in fractures in thin, weakly muscled people — i e, only seven Kg of traction weight to 70 Kg of body weight If the fractured limb has been paralyzed or weakened by poliomyelitis, apoplexy or disease of or injury to the spinal cord, more than four Kg must never be used at the start

In traction by pin or wire through the femur itself the traction weight should be one Kg less than as though the traction were through the tibial tubercle

Three different methods are available for **treatment of fractures of the femur**

1 *Continuous traction*
   a Skeletal traction with pin, wire or clamp,
   b Skin traction with adhesive tape, skin-adherent or Unna's paste, or
   c Traction at the ankle with foot-slings or gaiters
2 *The plaster cast*
3 *Internal fixation of the fragments (osteosynthesis)* with the three-flanged nail of Smith-Petersen and Sven Johansson, with or without an attached plate, or with the medullary nail of Kuntscher for use in fractures of the femoral shaft Condylar fractures may be fixed with screws Plates and screws are far inferior to the medullary nail in fractures of the femoral shaft, since they do not in themselves ensure stable osteosynthesis

1 a **Continuous skeletal traction** is, if properly applied, the most effective, simplest, most suitable and least dangerous method in the initial treatment and often throughout the whole period of treatment in all fractures of the femur But if applied incorrectly its great dangers are

   a Distraction with all its disastrous results (Vol I/pp 25—27, and M N /pp 98—127), and

   b) Infection

1 b **Continuous skin traction** is far more difficult to apply than is skeletal traction It can correct excessive shortening in recent fractures, but it often leads to blisters and skin eruptions and possibly

sure ulcers if it is not skillfully applied. There is essentially no danger of infection or distraction with this method

1 c Continuous traction with foot-slings or gaiters is to be used only to avoid angulation in fractures which have nearly united If this method is used in recent fractures and adequate weight is put on, the pain from pressure becomes unbearable after even one or two hours and pressure ulcers develop if the traction is not removed

For the initial treatment of most fractures of the femur from the femoral neck to its distal end we usually use pin or wire skeletal traction with the limb on a Braun splint, with overhead beams (fig 1604 a), on a thigh splint (figs 1605, 1606) or in a Thomas splint (fig 1612)

The following equipment is needed for **reduction** and further **treatment** by skeletal traction of a fracture of the femur·

1 Local anesthesia (Vol I/pp 118—120 and fig 152),
2 A—P and lateral roentgenograms (figs 1594—1596, 2001, 2002, 2010 and 2011),
3 A bed with firm support (fracture boards between spring and hair mattress) (Vol I/figs 99, 100 and 118; Vol. II/figs 1604 a and 1609—1611),
4 A properly prepared Braun splint (Vol I/fig 109; Vol II/figs 1604 a—d, 1611),
5 Two hoops for attachment to the Braun splint (Vol I/fig 109 b; Vol II/figs 1604 b—d);
6 A "baker" (light-cradle),
7 A hot water bottle or flask (fig. 1604 d),
8 A stainless-steel Steinmann pin 21 cm long and 4 mm. in diameter (Vol I/figs 126—128) or a stainless-steel wire (Vol I/figs 129—136),
9 A rotating stirrup for the pin (Vol I/figs 127, 128) or a tension stirrup for the wire (Vol I/figs 129—131),
10 A hammer for driving in the pin (Vol I/fig 128) or a hand-drill (Vol I/figs 132, 133), an electric drill (Vol I/figs. 134—136) or a compressed-air drill (fig 1696) for inserting the wire,
11. Two centrally perforated felt discs of 55 mm. diameter (fig 1613),
12 Two slightly curved, centrally perforated metal discs of 45 mm diameter (fig 1613),
13 Two 35 mm. long set-screws (fig. 1613),
14. A strap for securing the proximal thigh to the Braun splint (fig 1611);
15 A complete set of overhead beams with two fixed pulleys, four free pulleys, a scissor-shaped spreader and two trapezes (Vol I/figs 117, 118, fig 1604 a), or a thigh splint (Vol I/fig 112, figs 1605—1607),
16 A wooden box 25 × 30 × 40 cm (or 10 × 30 × 40) (Vol I/fig 118, figs 1604 a—1606),
17 Steps or two wooden blocks for supporting the foot-end of the bed (Vol I/figs 118, 119, fig 1604 a) or an adjustable-frame bed (figs 1609, 1610),

18 Five to ten traction weights of 1 Kg each, including one or two carriers (Vol I/fig 118, figs 1604 a—1606, 1611),
19 Two strong 5 mm thick hemp cords, 1 M and $1^{1}/_{2}$ M long (figs 1604 a—1606),
20 Fifty Gm of Unna's paste, a pot and a 10 cm broad brush (Vol I/fig 151),
21 A 10 × 10 cm gauze bandage (Vol I/fig 151),
22 A small wire spreader for skin traction with the Unna's paste forefoot dressing (Vol I/fig. 147, figs 1604 a—1606, 1611), *or*
23 A strip of adhesive tape 60 cm long and 5 to 6 cm broad and a centrally perforated 6 by 6 cm board, and finally
24 Skin adherent (e g , Mastisol)

Checking and Preparing the Equipment. As soon as a patient with a fracture of the femur is admitted, everything required for continuous traction is prepared and checked against the list on pages 1182—1183 to make sure that all is at hand and in order

Preparation of the Bed The surgeon should make sure that the bed is made as described in Vol I/p 97, and particularly that the fracture boards are firmly placed under the hair mattress and that they really support the mattress throughout the whole length of the bed Surprisingly enough, hospital administrators sometimes object to supplying such boards A perfect arrangement of the patient is impossible without them

Bandaging a Braun Splint The end of a 15 cm broad calico roller bandage is slit for 10 cm and the two resulting ends are tied round the central cross-bar of the basilar (horizontal) part of the splint Then three or four turns are wound round the proximal end of that basilar, horizontal part of the splint, for if the oblique part were covered first the bandage would soon slide up the inclined plane and the two proximal corners would lie bare and would press up against the patient's buttock Then the bandage is carried round the angle up onto the oblique part of the splint and this is bandaged with even, firm turns as far as the knee-angle In the region of this knee-angle the bandage must be very tight, but distal to it there should be loose turns of the bandage to allow for the calf (figs 1606, 2374—2378) For the lower half of the leg the bandage should be tight again To avoid pressure on the heel, the last quarter of the splint should not be covered (fig 2378) The vertical part of the splint is also left uncovered to give room for the longitudinal traction Many surgeons pad the proximal corners of the splint to avoid pressure against the buttocks This padding is superfluous and often harmful and should not be applied The corners of the well-prepared splint press against the buttocks only if the bed is too soft, so that the buttocks sink in deep, but never if the mattress is firm and if fracture boards are put under it the whole length of the bed (Vol I/figs 99, 118, figs 1604 a—d) It is also unnecessary, therefore, to shorten or round-off the proximal corners of the splint The position of the patient is only made worse by doing that

Adjustable Splints In 1916 I devised an adjustable splint For various reasons I simplified it until, in 1918, it was as shown in figure 1607 In 1930

I added a fourth pulley (Vol I/fig 112, figs 1605, 1606) Tens of thousands of femoral fractures in many countries have been treated on this thigh splint.

As a consulting surgeon I have seen a great number of adjustable splints Most of them, however, had not been properly adjusted Kirschner had the same experience He writes "But the best splints are useless *if they are badly adjusted and incorrectly applied* And that happens more often than not. I frequently found that the thigh part of my splint of 1928 had been so adjusted that the patient's thigh was hanging free without support Very often the length of the thigh part of the adjustable splint is *not adjusted to the patient's thigh*, and the splints are applied indiscriminately in the same state as when packed and delivered by the factory Once the splint is covered and has been used for one patient, hardly anybody ever thinks of readjusting it when it is going to be used for another patient of different size"[1]

From these experiences it seems best to use simple, nonadjustable splints.

Centrally Perforated Felt, Slightly Bent Metal Discs, and Long Set-Screws (Fig 1613) If the bone is sound and has a normal calcium content, pins or wires penetrating it do not slide, as a rule, if no inflammation develops But they slide very soon in bone with a poor calcium content if nothing is applied to prevent it Formerly we slit the felt and metal discs from the edge to the center But since they then often came off, we now perforate them in the center and thread them over the nail or wire before applying the stirrup They are fixed with a set-screw 35 mm. long Application of the discs is very difficult if the screws are so short as not to protrude beyond them The perforation of the discs is 0 5 mm wider than the points of the set-screw fixtures, allowing the discs to tilt a little and to adjust themselves The felt and metal discs and set-screws are put on the pin or wire first The rotating stirrup comes then outside them

Comparison of Pin, Wire and Clamp Traction

Pin Traction Codivilla in 1903 was the first to drive a pin through the os calcis in order to exert strong continuous traction during the application of a plaster cast In 1907, Steinmann introduced the pin in place of adhesive tape for traction in fractures His pin was a held by a two-piece stirrup to which the traction cord was fastened Encouraged by his work, many surgeons soon began to apply pin traction, since skeletal traction was seen to have many advantages over skin traction with adhesive tape But it was found that it was often followed by inflammation of the pin-holes and sometimes the formation of discharging sinuses Steinmann's advice was to leave the pin in the bone for not more than three or four weeks in order to avoid complications

Clamp Traction A number of surgeons suggested the use of clamps to avoid infections passing on through the whole pin track The clamps of Schmerz and the pliers of Reh were most frequently applied The points of the

[1] Kirschner, M Randbemerkungen zur Kriegschirurgie in den Heimatlazaretten, Berlin, OKW Press 1942

clamps usually had a big diameter and rotated in the bone when the patient moved, often causing infection

Wire Traction During the Balkan War, in 1912, Klapp used a wire instead of a pin for traction on the calcaneus, thus keeping the wound in the bone smaller But wire traction was little used in the first World War. It came to be generally applied only after strong tension stirrups had been suggested by Beck in 1924 and by Kirschner in 1927

Pin-track infection develops usually because the pin or wire and its stirrup, or the clamp and its ends, are firmly fixed to one another so that if the patient with traction through the femur moves or lifts himself onto the bedpan, etc , the bone rotates round the pin or wire or clamp Ultimately the metal becomes loose in the bone and infection develops and may pass on through the bone if the metal is not removed in time Wire, with its small diameter, causes infection less frequently than do pins or clamps applied in this way

The Rotating Stirrup To avoid this trouble I have since 1916 used a rotating stirrup[1] This stirrup is not firmly fixed to the pin but is free to rotate round it in two grooved bushings, one on either end, which are themselves held fast to the pin by set-screws (Vol I/figs 126—128). I devised this stirrup to allow free active movement of the knee joint in skeletal traction applied below the knee, though I soon gave it up for that purpose But I had noticed that the number of cases of pin-track inflammation was markedly lower when these rotating stirrups were used

Since 1918 I have used the rotating stirrup in about 3000 fractures of the femur, 4000 fractures of the leg and 1000 fractures of the os calcis for a total of more than 400,000 days in traction In infected gunshot-fractures of the femur and leg, the pin with rotating stirrup was sometimes left in place for from four to six months without complications Now we usually remove it sooner

Advantages of the Pin with Rotating Stirrup over the Wire I have kept to the pin and rotating stirrup mainly because it is far cheaper than the tension stirrup, far easier to apply, and much lighter and therefore easier to transport in war A thigh pin with rotating stirrup weighs 150 Gm , the big Kirschner stirrup weighs 600 Gm That means that there is four times as much valuable material in Kirschner's stirrup Besides, special hand drills with guidance instruments are required to insert the wire and strong "tensers" or calipers to tense it To prevent lateral sliding of the wire, metal and felt discs must be applied Fractures of the wire are not infrequent Contrariwise, an ordinary hammer from a surgical instrument case or even from a tool box is all one needs for driving in the pin Sliding of the pin seldom occurs in a sound bone if the pin is driven in properly, and pins very seldom break They are easily sterilized

Many pupils of mine who worked as surgeons in the Abyssinian, Spanish and Chinese wars and in the Second World War reported that they never

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[1] Bohler, L Simple Apparatus to allow Movement During Treatment of Fractures of the Femur (in German) Wien klin Wochenschr *30* 723, 1917

could use wire traction in mobile warfare because some part of the equipment — e g, a screw or a "tenser" or a stirrup or a part of the electric drill — was usually missing Or, when an electric drill and everything else was at hand, there was no electricity Only when the war had been stationary for five or six months were they able to apply wire traction But most of them had pins with rotating stirrups with them and could apply them at any time If only pins are available, but no rotating stirrups, one can fix the traction cords immediately to the pin as an emergency measure

Most young surgeons are afraid to use pins because they have heard again and again that they are dangerous. I have now and then seen a hospital's supply of tension stirrups exhausted by a sudden and unexpected increase in the number of fracture admissions, the surgeons then turning to treatment with adhesive tape skin traction or even to plaster casts despite the fact that there were pins in their instrument cases

On the basis of my own good experience in treating about 800 fractures with pin traction, I can again recommend it — provided it is used with the rotating stirrup

Size of Pins and Stirrups I use pins 4 mm in diameter and 15 cm or 21 cm long, the shorter ones for traction through the os calcis and the longer ones for traction through the tibial tubercle or through the femur above the condyles The rotating stirrup for the short pin is 17 cm long, that for the long pin 27 cm long If the pin is applied below the knee during initial treatment of femoral fractures and then above the knee in the fourth week when the swelling of soft tissue has subsided, the 21 cm pin is always long enough A pin driven in above the knee in a recent juxta-articular fracture of the femur may prove too short if there is severe swelling, and the stirrup will then press into the skin

Should Skeletal Traction Be Exerted Above or Below the Knee Joint? In recent fractures, with the exception of femoral neck fractures, we always put the pin through the tibial tubercle and not through the femur, since many surgeons have observed that use of the pin or wire — and particularly of the clamp — above the knee joint may lead to severe complications Empyema of the knee joint, infection of the hematoma in fractures close to the knee joint followed by osteomyelitis, ankylosis of the knee joint, amputation and death have been observed Fritz Lange has given a comprehensive report on such cases (see page 1187) Insertion of the pin through the tibial tubercle precludes the danger of penetration by it of the joint or of the hematoma The tubercle of the tibia is particularly strong, of course, because the tendon of the quadriceps inserts there That the pin might cut out through this bone is hardly likely. On the other hand, a clamp should never be applied there because it does not engage cortex deeply enough and may slip off along the tapering tibial shaft

How Long May Skeletal Traction Be Maintained Through the Tibial Tubercle? Traction through the tibial tubercle should not be allowed to remain for more than four weeks in order to avoid lengthening of the ligaments of the knee If traction is exerted for not longer than five or six weeks, the knee usually

recovers again after some months But if it is allowed to remain over a still longer time the knee may remain loose and tender permanently, and sometimes a frankly unstable knee joint develops If traction on the femur must be exerted for longer than four weeks, we remove the pin from the tibial tubercle in the fourth week and insert another above the knee, being careful to avoid the suprapatellar pouch

Should Skeletal Traction or Skin Traction Be Applied in Recent Fractures of the Femur? In recent fractures of the femur, skeletal traction using pin or wire is preferable to skin traction with adhesive tape, Unna's paste bandage or any other traction bandage because stronger traction can be exerted through it Moreover, the insertion of a pin with the patient's limb on a Braun splint takes only a few minutes, while the application of a skin traction bandage takes a quarter of an hour or longer During that period the fractured limb is perhaps painfully moved about Besides, every skin traction bandage tends to damage the skin — a serious drawback in the initial treatment

The Dangers of Continuous Traction with a Pin or Wire

The dangers of continuous skeletal traction are *infection* and *distraction*

If the skin is pulled sideways when the pin or wire is inserted and therefore "tented" by it, local necrosis of the skin may result, followed possibly by *infection* of soft tissue and of bone — or infection of the joint if the pin or wire was inserted through a joint Sliding of the pin or wire in its track leads to the same complication Infection may also result if a pin is driven through the compact shaft of a bone and a piece of the shaft breaks away The pin then becomes loose and slides in its track Heinrich [1] noted infection of wire sites in 13 per cent of the femoral fractures he treated Fritz Lange, writing after World War I, said on page 8 of his book [2] "As a consulting surgeon during the war I saw some twenty cases of knee ankylosis which had developed after pin traction in gunshot fractures of the femur The pin had caused infection of the knee joint which resulted in ankylosis"

It should be noted here that before the introduction of antibiotics ankylosis was the *best* end-result in severe infections of the knee joint One could reckon that usually one third of the cases would result in death through sepsis, the second third in amputations, and the last third would heal with ankylosis

Local osteomyelitis and cellulitis of the thigh are far more frequent than infection of the knee joint Sinuses may form and continue discharging for a long period and, as a rule, they close only after removal of small ring-shaped sequestra Sometimes they persist in spite of sequestrectomy and administration of antibiotics In some cases they break down again after many years All this shows that pin or wire traction can be dangerous unless it is

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[1] Heinrich, G Zur Frage der Drahtextension und des kombinierten Drahtzuggipsverbandes im Felde Der Deutsche Militararzt *8* 586, 1943

[2] Lange, Fritz Die Behandlung der Knochenbruche durch den praktischen Arzt, Munich, Lehmann, 1933

kept under constant observation Figure 1614 shows the results of a severe case of pin-track infection

The cases of *distraction* with skeletal traction far outnumber those of infection Distraction is the result of too much traction weight The damages caused by it are described in Vol I/pp 25—27 and in M N/pp 98—127. If traction is exerted across the knee joint for more than four weeks, that joint becomes loose

Avoidance of the Damages of Pin or Wire Traction

Infection of the knee joint can be avoided if care is taken not to drive the pin through the joint and if a rotating stirrup is applied Infection from a sliding pin or wire can be avoided by not driving the pin through the shaft and by daily checking the pin or wire site The sliding of pins can be prevented by the application of padded metal discs (fig 1613) If infection occurs in spite of these precautionary measures, the pin or wire must be removed at once

Distraction can be avoided by not using too much traction weight and by seeing to it that the check roentgenograms always show a slight shortening of 1—10 mm and never a lengthening The control and regulation of continuous traction is easy if standard weights are used

APPLICATION OF PIN OR WIRE TRACTION IN FRACTURES OF THE FEMUR

Local Anesthesia. After the clinical examination, as described on pages 1073 and 1082, and after having gone through the questions on page 1088, local anesthesia as described in Vol. I/pp 118—120 is given before lifting the patient from the stretcher onto the X-ray table Then he can be positioned on the table without pain Thus we win his confidence from the first moment and establish a favorable personal contact with him The fracture site can easily be found through eliciting of tenderness on pressure, and sometimes it is indicated by the deformity of the limb 20 ml of a 2% procaine solution are injected at the fracture site as soon as the needle touches the bone. The pin or wire sites are anesthetized by injecting 5—6 ml of a 2% procaine solution on each side of the tibial tubercle

Roentgenograms If the anesthetic has been well given, pain ceases at once The patient can then easily be arranged on the X-ray table in such position that good A—P and lateral views can be obtained (figs 2001, 2002 and 2010, 2011)

Moving the Patient into a Warmed Bed and Placing the Limb on a Braun Splint After the roentgenograms have been made, the patient is lifted into a bed which has been warmed with a "baker," and the limb is placed on a properly covered (see page 1183) Braun splint

Driving in the Pin The sterilized Steinmann pin is held in a sterile sponge and driven through the bone by some vigorous hammer strokes It should be introduced 1—2 cm behind the anterior tip of the tibial tubercle and at exactly right angles to the long axis of the bone. An assistant firmly holds

the limb proximally and distally to the site of pinning For psychological reasons the patient's eyes are covered If the pin is driven in from medial to lateral, the skin is drawn in medially and pushed out laterally It should be smoothed with the fingers to avoid circumscribed necrosis of the skin One of my assistants used to pull the pin back with rotatory movements until the skin was smooth laterally. In many of these cases inflammation and suppuration started after a few days, probably because the pin had been slightly loosened by the rotatory and pulling movements Formerly we painted the pin holes with Mastisol and put on an sponge with balsam of Peru Now we usually leave the skin exposed Thus a beginning inflammation is noticed at once and the pin can be removed in time

Applying the Rotating Stirrup and the Cap Protecting the Point of the Pin The stirrup is put on both ends of the pin and fixed with the two set screws (Vol I/figs 127, 128) A piece of cork or a metal cap is put over the pointed end of the pin so that no one can be injured by it We usually arrange all three screws pointing in one direction It takes little time and looks nicer

Fixing the Two Supplementary Iron Hoops They are fixed to the Braun splint to prevent the blanket from disturbing the sites of the pins and from pressing on the traction cord

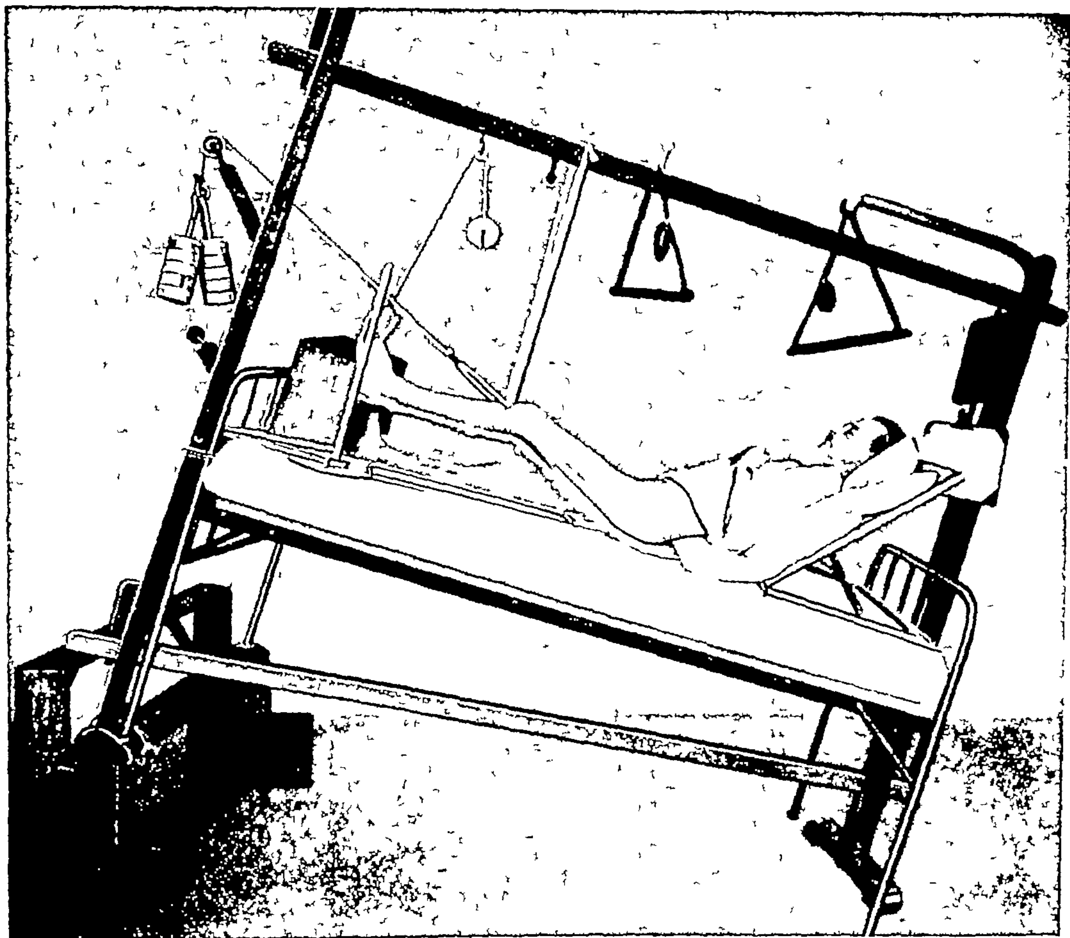
Fastening the Thigh to the Braun Splint The thigh is secured to the proximal end of the Braun splint by means of a strap

Drilling the Wire and Applying the Tension Stirrup The wire is drilled through the bone with an ordinary hand drill (Vol I/figs 132, 133), an electric drill (Vol I/figs 134—136) or a compressed air drill (fig 1696) Then it is tightened in a tension stirrup (Vol I/figs 129—131) If it is not tightened enough it will become crooked and press upon the skin, thus causing pressure necrosis and infection

Applying the Traction Cord The 5 mm hemp cord is attached to the ring of the stirrup with a knot after its end has been previously knotted. Thus the cord will never slip off even if attached only with a single knot Frequently several knots are tied on top of each other without the end of the cord's being tied into a knot. All this tying takes much time, to say nothing of that needed for untying those knots again if any alteration becomes necessary Moreover, with no knot in its end, the cord can still slip off For longitudinal traction the cord is led over the Braun splint and the lower end of the bed and a suitable traction weight (see page 1179) is attached to it

Adjusting the Gallows, Fixing the Scissor-Shaped Spreader, and Placing the Wooden Foot-Rest Now the patient is taken to his room The lower end of the bed is raised 50 cm on the wooden steps, on two wooden blocks or on some other device (Vol I/figs 91, 92, fig 1604 a) Thus the body weight is used as countertraction Countertraction by means of a perineal band is not advisable because it is irritating and uncomfortable In fractures of the upper shaft, the longitudinal overhead beam, or "gallows," crosses the bed obliquely with its foot end near the corner of the bed on the injured side and its head end near the corner of the bed on the sound side The broken

limb should never be abducted so far that the foot comes to lie outside the bed and the abductors are, therefore, overstretched In fractures of the lower shaft the gallows is set up in the long axis of the bed, being fixed to the foot of the bed and to the steps The wooden foot-rest, size 25 by 30 by 40 cm or 10 by 30 by 40 cm, is placed on the sound side so that the patient can press against it with the sound foot (fig 1604 a) Then the scissor-shaped



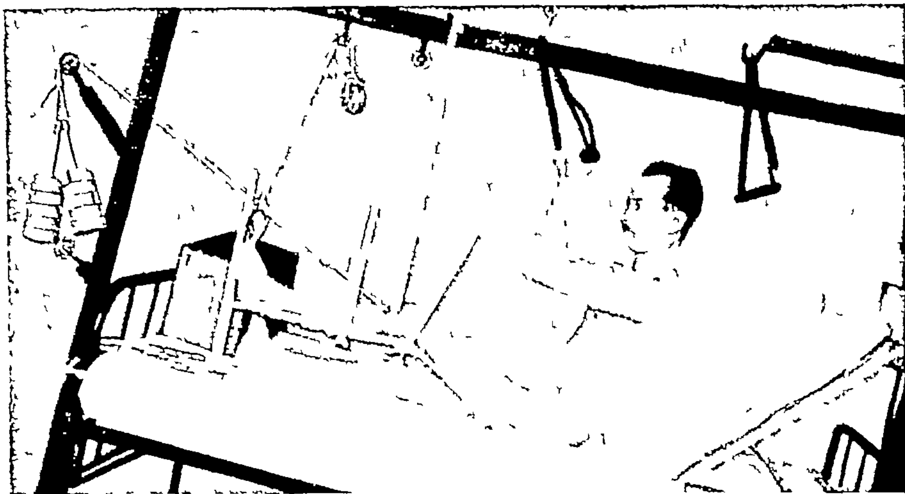
1604 a

Fig 1604 a—Treatment of a femoral fracture with pin traction A bed giving a firm support (boards between hair and spring mattresses) The foot of the bed is raised 50 cm Wooden overhead gallows with pulleys The fractured limb is placed on a Braun splint The tibial traction is weighted with 10 Kg, the fore-foot with 1 Kg For internal rotation of the limb the lateral end of the pin is fastened to the gallows The foot of the sound limb is propped against the foot rest (wooden box)

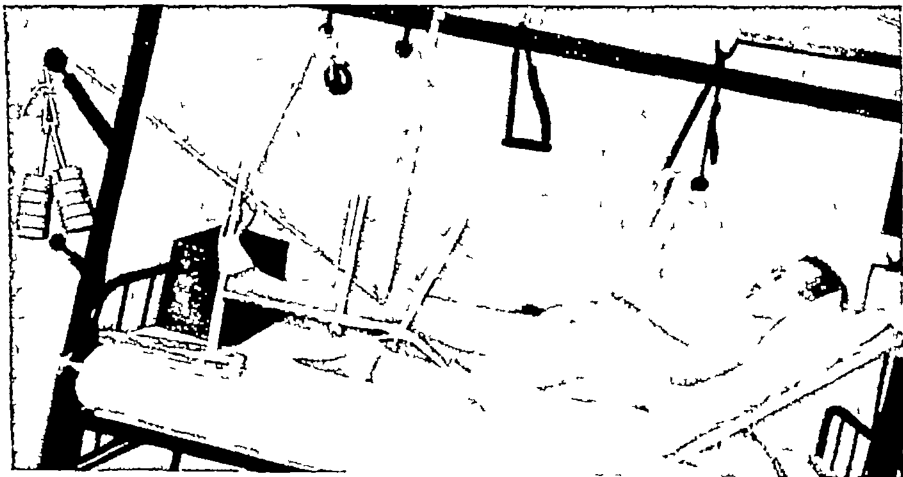
Fig 1604 b—The patient is able to sit up by pulling himself up on the distal trapeze The hip is flexed by sitting up Two hoops are attached to the Braun splint to prevent the bed cover from pressing on the pin

Fig 1604 c—Holding onto the proximal trapeze and supporting himself on the sound limb, the patient is able to raise his pelvis, so just one nurse can help him with the bed pan, clean him and make the bed

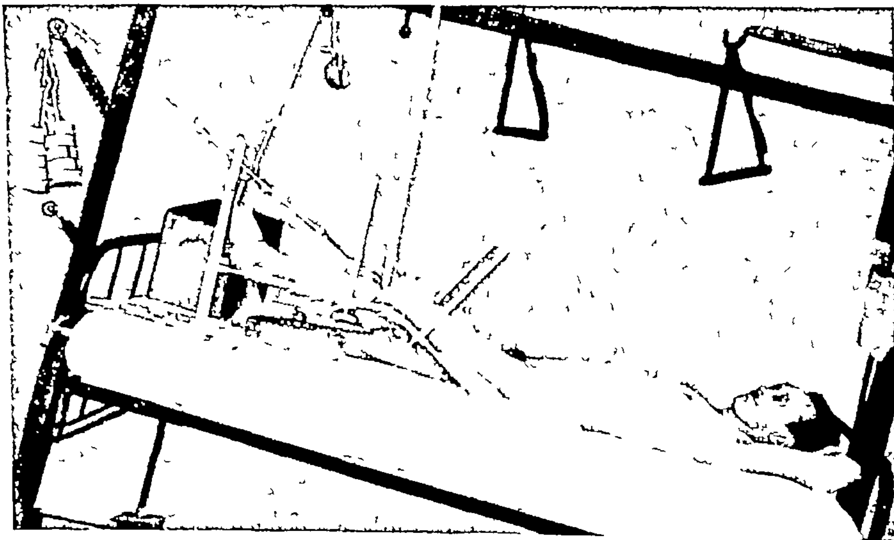
Fig 1604 d—After the fourth week the patient should lie flat for five to fifteen minutes daily to avoid flexion contracture of the hip A hot water bottle lies under the Braun splint to prevent the limb from chilling



1604 b



1604 c



1604 d

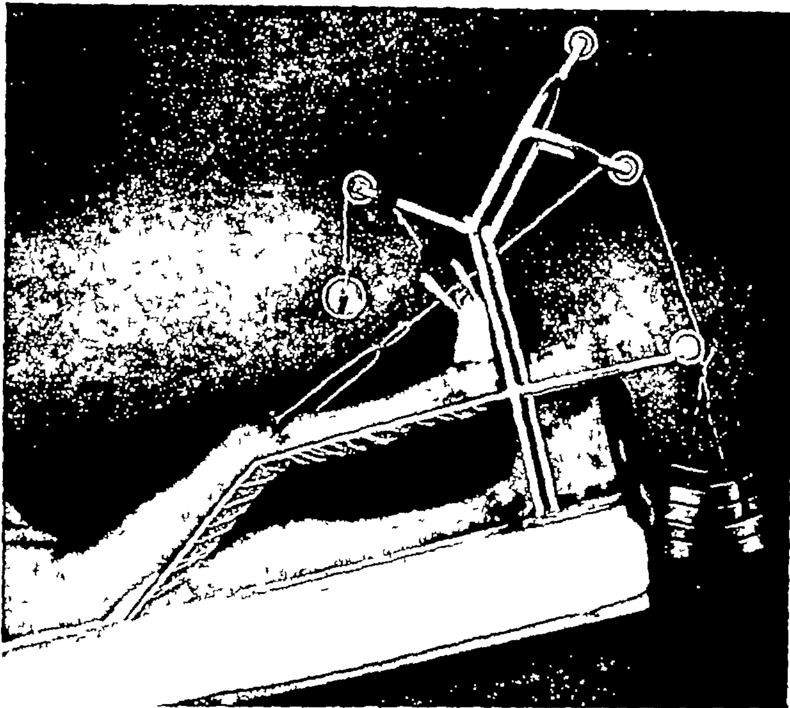


Fig 1605—Limb with a fracture of the femoral shaft on a thigh splint The foot of the bed is raised 50 cm The sound-side foot is propped against a wooden box Boards between the spring and hair mattresses The bed is perfectly flat and the splint cannot tip Skeletal traction is exerted through the tibial tubercle The weight of traction is 9 Kg in a patient of 65 Kg, i e, one-seventh of the body weight Unna's paste dressing has been applied to the fore-foot for traction with 1 Kg The traction cord runs over the lower pulley, slightly below the long axis of the thigh

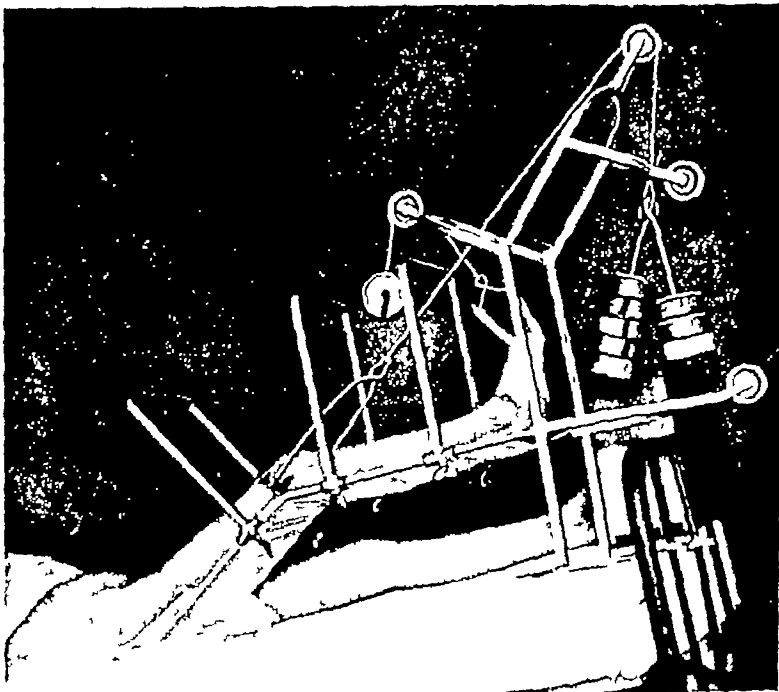
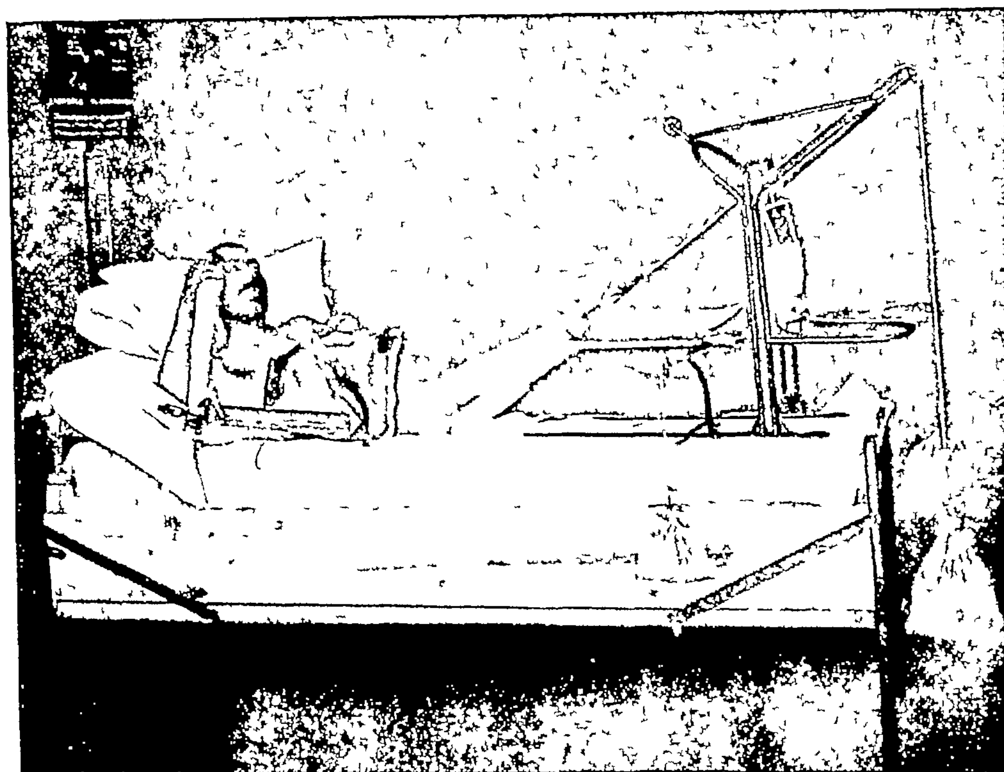
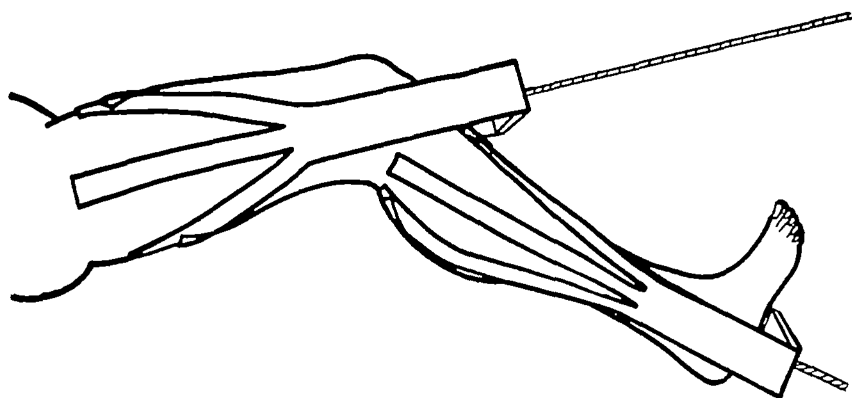


Fig 1606—Comparison picture re figure 1605, four weeks later Pin traction is now exerted above the knee The weight of traction is 8 Kg in a patient of 65 Kg, i e, one-eighth of the body weight The traction cord runs over the upper pulley, slightly above the long axis of the thigh Three supplementary iron hoops are attached to the splint to prevent the bed cover from pressing on the limb or on the pin



1607, June 12, 1918

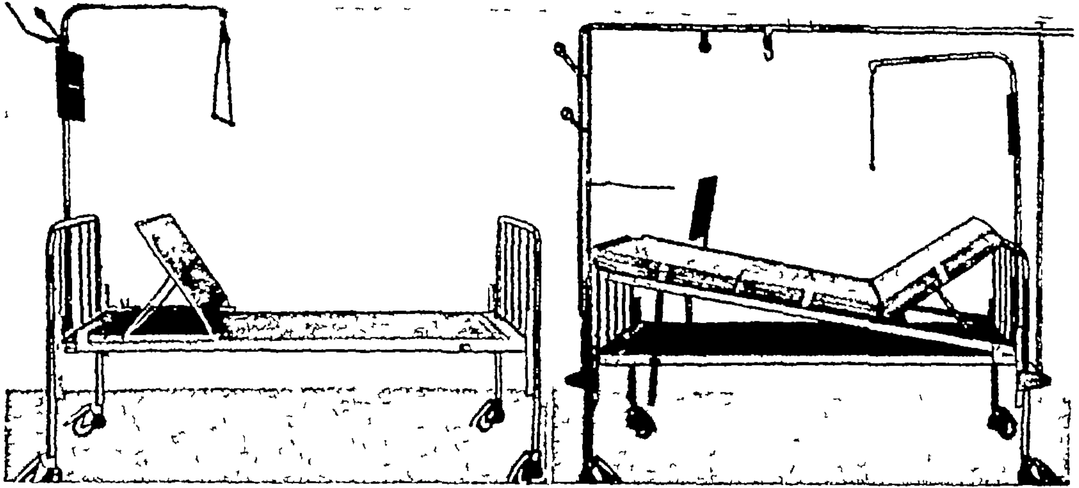


1608

Fig 1607—Application of continuous traction in multiple fractures an infected fracture of the femur, compound fractures of the tibia and fibula, and a closed fracture of the humerus Schmerz's bone clamps are applied to the femur and calcaneus The sites of entry and exit of the pin were at this time still covered with sterile sponges Adhesive tape traction of the forefoot and wooden spreader Lateral traction applied to the leg Double right-angle splint for the humerus The foot of the bed is not raised

Fig 1608—Application of adhesive plaster for the treatment of fracture of the femur The traction bands should be trisected not less than a hand's breadth above the knee and the ankle, otherwise they will cut into the skin

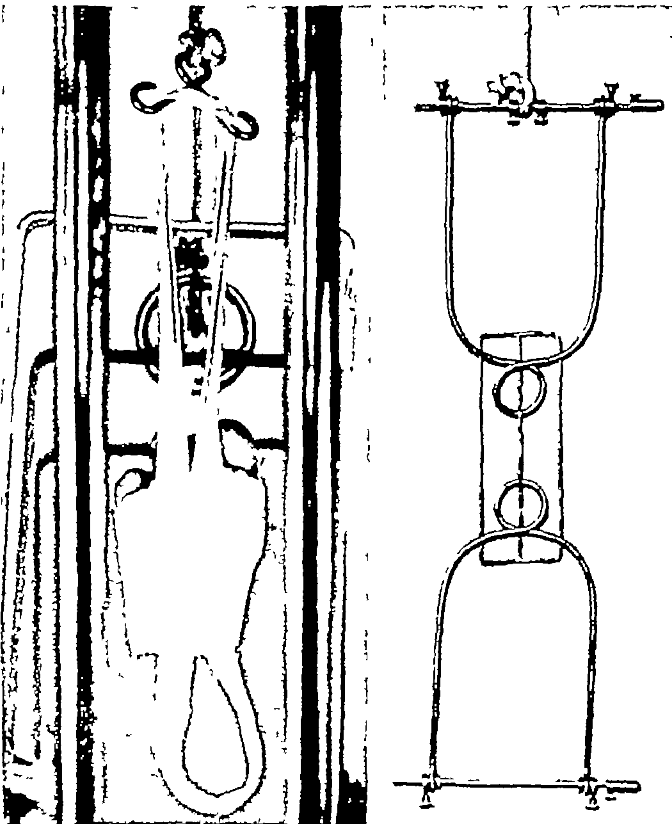
spreader (Vol I/fig 90) is connected to the Braun splint and the gallows in such a way that in fracture of the upper shaft the point of flexion of the knee coincides exactly with the point of angulation of the splint or so that in fracture of the lower shaft the point of knee flexion is 4 to 8 centimeters distal to the point of angulation of the splint These regulations of the level



1609 1609 a

Fig 1609—Original form of the Linz bed with adjustable frame The bed is mobile, back-rest under the mattress The patient's blackboard and temperature chart are attached to the trapeze frame Above the blackboard there are two pulleys for exercising the arms

Fig 1609 a—The bed adjusted for skeletal traction on the femur The extension frame carrying boards and foam-rubber mattress is raised at the lower end by means of two perforated struts The extension gallows is adjustable At the foot there are two pulleys and one scissor-shaped spreader for the Braun splint, adjustable in slots On the overhead connecting bar there is one adjustable pulley for traction on the foot, a suspensor for the second trapeze, and metal pins for rotary traction and suspension Bed and extension gallows are made of chromium-plated steel



1610 1610 a

Fig 1610—Unna's paste traction to the forefoot The sling, 2 5 cm broad and consisting of a 10 cm broad calico bandage folded twice lengthwise, is applied round the heel and extends to the wire stirrup passing beneath the second and fourth toes A cord leads from the stirrup over a pulley to a traction weight of 1 Kg The two parts of the sling are fastened to the forefoot with Unna's paste and muslin bandages

Fig 1610 a—Two rotating stirrups with Steinmann pins are connected by means of a metal frame This is a device for lowering longitudinal traction as far down as to the level of the metatarsus in supracondylar fractures of the femur

FIG 1611—Forty year old sturdy patient, weighing 65 Kg, with supracondylar fracture of the left femur, on the Linz extension bed The bed is horizontal The lower end of the frame with longitudinal boards and foam-rubber mattress is raised 50 cm The fractured limb is positioned on a Braun splint Longitudinal traction is lowered and leads over the metatarsal heads This is facilitated by another rotating stirrup fastened to the first one and leading over the forefoot Longitudinal traction of 9 Kg, Unna's paste forefoot traction of 1 Kg

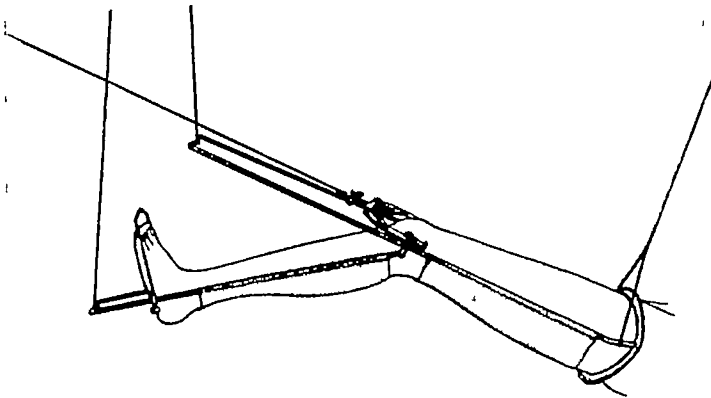


FIG 1612—Fracture of the femur treated in a Thomas splint with a Pearson attachment to allow flexion of the knee This splint is used mostly in Great Britain and the United States The picture is taken from the catalogue of the Zimmer Company, Warsaw, Indiana

of the knee to that of the point of angulation of the splint should be made while the patient presses against the foot-rest with the sound-side foot The scissor-shaped spreader prevents sidewise as well as longitudinal motion of the splint and so prevents exertion of traction in valgus or varus direction Because of the support provided by the sound-side foot against the foot-rest, position of the body relative to splint and gallows remains unchanged The fixed pulley is so arranged that in fracture of the upper shaft the traction cord lies in the direction of the long axis of the femur (figs 1604 a, 1606) In fractures of the lower shaft the cord must be lowered so as to lie close above the toes or at the level of the metatarsus (figs 1605, 1611, 1997—1998 b, 2005—2008) The cord between pulley and carrier-hook must not be longer than 10 to 20 cm in order that the weights not touch the gallows frame

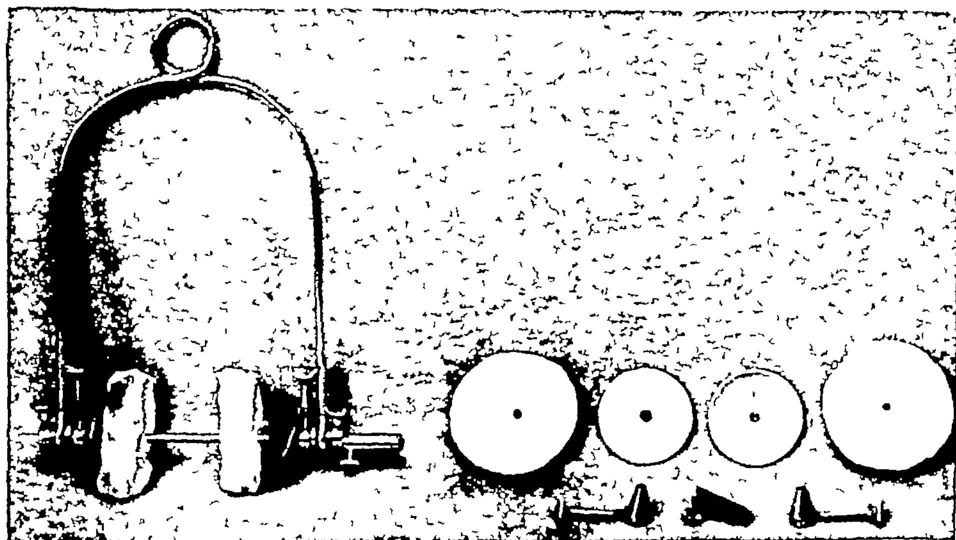


FIG 1613 —Rotating stirrup with Steinmann pin, two perforated discs of felt 10 mm thick, with a diameter of 55 mm , two convex metal discs with a central hole and a diameter of 45 mm , two regulating screws 35 mm long, and a metal cap with short set-screw to guard the point of the pin Assembled on the left, displayed separately on the right

Neither, of course, should the weights be allowed to rest on or against the bed or a chair The pulley for traction on the forefoot should be positioned above the middle of the tibia

Application of the Unna's Paste Forefoot Sling After longitudinal femoral traction has been applied, forefoot traction is applied For this we use a 2 5 × 100 cm. strip made from a 10 × 100 cm gauze bandage twice folded lengthwise First the edges and then both ends are sewn together, making a sling 50 cm long The forefoot and a narrow strip proximal to the point of the heel are painted with paste Then the sling is applied so that it supports the heel and runs from both sides thereof across the sole, the medial strip running under the second toe and the lateral one under the fourth toe Both strips are painted on the outside with Unna's paste in the region of the forefoot A muslin bandage of 10 cm is loosely wound round six times and is painted with Unna's paste (fig 1610) It must not be too tight

When the Unna's paste has dried for an hour, the small wire stirrup (Vol I/ fig 147) is placed in the upper end of the sling The traction cord is fastened to it and is led over the pulley that has been attached over the middle of the tibia One Kg is usually used for traction (fig 1610) It prevents not only foot drop but also internal or external rotation of the leg And it guards the heel and Achilles tendon from pressure and bed sores, since the heel does not lie with its whole weight on the splint This is important, because pressure



FIG 1614 —Sequelae of pin track infection in a closed torsion fracture of the left femur in a 28 year old man Fracture of the femur in 1934 at the age of nine when skiing Immediate admission to a hospital where wire traction was exerted through the distal end of the femur Swelling and reddening of the knee-joint region, severe pain, and fever up to 102 2 F after 10 days The wire had probably penetrated the joint capsule and was removed, and the limb was placed on a metal limb splint Septicemia with pleuritis and pericarditis during the following six months, in spite of several incisions for drainage In addition, thrombophlebitis of the left arm after blood transfusion A plaster hip spica was applied only after six months Then temperature subsided gradually Transferred to a solar sanatorium for eight months during the summer of 1936 Stayed in hospitals for over two years altogether Discharged with orthopedic splint and persistent thigh fistula Bony union of the fracture only $2^1/_2$ years after the accident Bony ankylosis of the knee-joint Permanent draining sinus for 19 years, sometimes high temperature with abscess formation and severe pain Thigh shortened by 14 cm Pronounced foot-drop position, ankle and sub-talar joints practically stiff Several scars and two fistulae on thigh and about knee-joint Bony union of the femur with varus angulation of 30^0 Near the original site of the fracture, a small cavity with sequestra Since the fistulae did not close in spite of sequestrotomy and use of penicillin, streptomycin and other antibiotics, a high thigh amputation was done in healthy tissue

sores on the heel do not recover for months and leave scars that may break down even years later As the traction cord is not made fast but is made to run over a pulley to a weight of 1 Kg , active and full-range movements of the toes, ankle-joint and talocalcaneal joints are always possible Limited motion of these joints and muscle-wasting are thus prevented, and circulation remains satisfactory

Application of Forefoot Traction by Adhesive Plaster Adhesive plaster may be used instead of Unna's paste A strip of adhesive plaster 60 cm long,

as shown in Vol. I/fig 695, a wooden spreader of 6 by 6 cm, perforated in the middle, a traction cord, skin adherent, and two tongue-spatulae are needed Tape is applied to the forefoot in such a way that the wooden spreader is 1 cm from the tips of the toes The outer side of the adhesive plaster is painted with skin-adherent A gauze bandage, 10 cm broad, is wound round 5—6 times It is painted with a little skin adherent to prevent it from sliding off Skin adherent must not be used profusely, lest the bandage become stiff as a cake of strong glue and cause pressure sores Care should be taken that toes, ankle and heel not be included in the bandage to allow immediate recognition of circulatory disturbances and paralysis of the peroneal nerve Stockinette tubes covering the toes, for example, would be in the way

Prevention of Rotary Displacement of the Fractured Limb The limb frequently tends to rotate outwards If this cannot be prevented by foot-traction alone, the outer end of the pin is tied to the gallows with a strong calico bandage (fig 1604 a) Position as regards rotation is satisfactory when the limb is as described on pages 1189—1197 with the inner side of the foot vertical (fig 1610)

Questions We Should Ask Ourselves in Order to Avoid Mistakes When Examining Fractures of the Femur

These are the same as in the examination of dislocations of the hip (see page 1082) and fractures of the femoral neck (see page 1173)

Questions We Should Ask Ourselves When Treating Fractures of the Femur in Skeletal Traction

1 Have I treated the shock (if any) prior to the clinical examination and before taking roentgenograms?
2 Have I warmed the patient quickly with hot blankets, hot beverages and light-cradle in order to combat shock?
3 Have I given local anesthesia in order to combat shock?
4 Have I, at the same time, given local anesthesia on both sides of the tibial tubercle?
5 Have I given blood or plasma in time if warming and local anesthesia were ineffectual in combatting shock?
6 Have I ordered everything neccessary for treatment as described on page 1182 immediately after making the diagnosis?
7 Have I examined all appliances for completeness and condition?
8 Have I checked as to whether sufficiently long fracture boards are placed adequately between spring and hair mattress (Vol I/fig 99)?
9 Have I checked as to whether the hair mattress is sufficiently upholstered (fig 1604 a)?
10 Have I warmed the bed in advance with a light-cradle?
11 Have I properly covered the Braun splint or the thigh splint with bandages (see page 1183)?
12. Have I avoided using adjustable splints (see page 1184)?
13 Have I used a uniform set of weights (figs 118, 1604 a, 1606)?

14 Have I suspended the weights on a carrier instead of tying them with a cord?
15 Have I taken exactly frontal and exactly lateral roentgenograms, i e, in both major planes?
16 Have I put the patient into the warmed bed and placed the limb on the Braun splint after having read the roentgenograms?
17 Have I covered the patient's eyes to prevent him from watching the insertion of the pin?
18 Have I seen to it that the limb was held firmly both proximal and distal to the site of the pin?
19 Have I been careful to insert the pin definitely distal to the knee joint to avoid possible infection?
20 Have I inserted the pin exactly horizontally through the bone, and not obliquely?
21 Have I, after driving in the pin, lifted the skin drawn in on the medial side and pressed a finger against the skin bulged out on the lateral side in order to prevent skin necroses?
22 Have I left the entry and exit points of the pin uncovered in order that I be able to examine them at every rounds, to discover inflammations at once and to remove the pin in time?
23 Have I applied a freely revolving stirrup (see page 1185)?
24 Have I protected the point of the pin with cork or a metal cap with set-screw to prevent injuries?
25 Have I applied all set-screws in the same direction?
26 Have I fixed the two supplementary hoops to the Braun splint?
27 Have I fixed the thigh to the proximal end of the Braun splint by means of a strap?
28 Have I tied the traction cord into a knot at one end?
29 **Have I avoided using too heavy weights for longitudinal traction** (see page 1179) to prevent separation of fragments, delayed callus formation, non-union, and disturbances as described in Vol I/pp 25—27, and M N/pp 98—127?
30 Have I taken into account the patient's general condition, his age, and the condition of his muscles when determining the traction weight?
31 Have I used weights of less than 5 Kg in cases of paralysis?
32 Have I seen to it that the traction cord between pulley and carrier is not longer than 10—20 cm?
33 Have I seen to it that the weight does not lie on or get caught in the bed or a chair, thus losing its efficiency?
34 Have I raised the lower end of the bed by 50 cm?
35 Have I, in fractures of the upper shaft, adjusted the gallows so that it crosses the bed in an oblique direction, its foot end being near the corner of the bed on the injured side and its head end near the corner of the bed on the sound side, or, in fractures of the lower shaft, so that it is in the long axis of the bed?
36 Have I avoided abducting the leg so far as to place the foot outside the bed?

37 Have I tied the gallows to the foot of the bed and to the wooden steps?
38 Have I placed a foot-rest on the side of the sound leg?
39 Have I connected gallows and Braun splint?
40 Have I seen to it that the point of flexion of the knee corresponds exactly with the angle of the splint in fractures of the upper shaft and that it is 4—8 cm distal to the angle of the splint in fractures of the lower shaft (figs 1613, 1997—1998 b, 2005—2008)?
41 Have I applied the traction cord in the long axis of the femur in fractures of the upper shaft (figs 1604 a, 1606)?
42 Have I lowered the traction cord in fractures of the lower shaft so that it lies close above the toes, or across the metatarsus (figs 1605, 1611, 1997—1998 b)?
43 Have I applied forefoot traction of 1 Kg ?
44 Have I applied this forefoot traction in such a way as to leave toes and heel uncovered?
45 Have I attached the pulley for forefoot traction above the middle of the lower leg?

Further Treatment of Fractures of the Femur in Skeletal Traction

Observation of General Conditions and Traction Weights When the surgeon enters the room on rounds he should find every patient with at least the fractured leg — or, better, both legs — uncovered He should glance quickly at all the patients to note skin color (as clinical indication of fever, anemia etc) and to note any indications of discomfort or pain

Checking the Traction Weights The surgeon should then briefly check the traction weights to be sure that they seem to be proper in each case relative to the patient's age, condition and body weight

Upon coming to the bed, the surgeon should check the temperature and pulse charts and should have the patient move his toes and ankle-joint through their full ranges of motion He should ask what exercises were carried out the previous day, how long those exercises lasted and whether they were painless or painful

Checking the Positioning. The Braun splint must be well prepared (see page 1183) and must be level It must not be tilted towards the center of the bed Superfluous cushions and pillows that are sometimes tucked between the limb and the splint or under the splint must be removed In fractures of the upper shaft the splint must point to the lower end of the bed on the injured side, in fractures of the lower shaft it must lie in the long axis of the bed In fractures of the upper shaft, when the sound foot presses against the foot-rest the point of flexion of the knee must correspond exactly with the angle of the splint The traction cord must lie in line with the long axis of the femur (fig 1604 a) In fractures of the lower shaft, the point of flexion of the knee should be 4—8 cm distal to the angle of the splint and the cord lowered so as to lie close above the toes or at the level of the metatarsus (figs 1605, 1611)

In order to prevent rotary displacement, the surgeon should make sure that the inner side of the foot is vertical and that the forefoot traction is in order

If the edge of the forefoot traction dressing pinches, it should be slit a little If the leg rotates externally in spite of forefoot traction, the outer end of the pin is suspended from the gallows by means of a calico bandage (fig 1604)

Observation of Pin- and Wire-Holes to Avoid Infections. The most unpleasant sequelae of skeletal traction are caused by infection of the spots where the pin enters and leaves Fortunately, sequelae of such a severe degree as in figure 1614, or as reported by Fritz Lange (see page 1187), occur very rarely But even slight inflammations may impair motion of the knee joint and prolong the treatment Therefore pin- and wire-holes must be inspected daily if they are exposed, or swabs and felt and metal discs must be removed if the patient complains of pain in these places Incipient reddening often disappears after application of a small alcohol-soaked sponge which is cut from one edge to its center and placed about the involved end of the pin If this has no effect, a new pin or wire must be inserted at another place and the old one removed

Supervision of Traction Weights to Avoid Distraction. The traction weights must be checked daily in order to avoid separation of fragments with all its complications as described in Vol I/pp 25—27, and M N/pp 98—127 Attention should be paid also to the length of that part of the cord between pulley and carrier, since if it is longer than 10 to 20 centimeters the weights may not hang free but may come to rest on or against the bed or a chair and thus be inefficient

Marking Site of the Fracture, and First Roentgen Control With longitudinal traction continuing, check roentgenograms are taken on the second or third day at the latest in both main planes, i e exactly anterior and lateral, with a portable machine These are made primarily to allow one to be sure that no distraction has occurred, as well as to show the direction and extent of possible angulation and/or lateral displacement To assist the roentgen technicians, the site of the fracture is marked with a red cross, it may also be useful to draw lines to indicate desired positions for upper and lower edges of the cassettes This guarantees to some extent the adequacy of the roentgenograms and makes it only rarely necessary to repeat them, thus saving time and material And incidentally, this practice tends to keep the surgeon himself always informed about exactly the site of the fracture During the First World War, I used to sketch the roentgen findings on the skin over the site of the fracture (figs 2121 d, e) so as to be continually informed about the site and the type of the fracture

Diminishing or Increasing Traction Weights In case of even the slightest diastasis between the fragments, the traction weight must accordingly be diminished by 1—2 Kg , in case of shortening by more than 10 mm , however, traction must be increased

Correction of lateral displacements and angulations by changing the direction of traction and other methods will be described later when the different types of fractures are discussed

Further Roentgen Controls The second roentgen control should be made after one week, further controls should be made every second week as a rule

In some cases more frequent controls will be necessary But one should not order them every 2 or 3 days and again and again try to improve fragment position, for frequent changes will delay callus formation and may even prevent it altogether

Bowel Care. The patient should have a bowel movement at least every other day. If he has not, as may happen particularly before his starting the systematic exercises, he should be given an appropriate diet and if this has no effect, a laxative or an enema

On the patient's blackboard the date of his admission to the hospital is noted in the top lefthand corner, the person or institution meeting the costs in the middle, and, in case of open wounds, any sensitivity to any of the various antibiotics in the top righthand corner If the dorsalis pedis and posterior tibial pulses are not palpable in case of injured lower limbs, a red P crossed by a dash is marked on the board The next line shows the patient's name and age, and further down are the diagnosis and the date of the accident The date of the last roentgen control is marked in the bottom lefthand corner and, in the middle, that of treatment, e g, date of operation, of application of an extension bandage, etc, and type of exercises with the date when they were started In case of wounds, the date when the dressing was changed for the last time is put down as well Thus the surgeon is kept well-informed about all that is essential I have noticed that in many places the patients' blackboards contained only their names and that nobody knew their cases, how long they had been sick, or what was being done for them Ideal treatment, however, is impossible without the above facts' being known at all times

Filling in Temperature and Pulse Charts. Besides noting temperature and pulse, the bowel action, drugs administered, types of exercises, and mobility of joints must be entered in the permanent chart

Grand Rounds As it is almost impossible to supervise all the details every day, we check the patients' blackboards and temperature charts once a week in order to be sure that everything has been correctly noted there, to check as to whether any drug can be dispensed with, and to learn whether the exercises are being carried out adequately and whether they should be changed Moreover, we review the whole series of well-labeled roentgenograms (Vol I/pp 90—92) on a portable viewing box near the bed in order to review the whole course of treatment It takes us about one hour for every 15 patients on our grand rounds

Questions We Should Ask Ourselves in order to Avoid Mistakes in Further Treatment of a Femoral Fracture in Skeletal Traction.

1 Have I paid daily attention to the patient's general condition?
2 Have I had uncovered the injured leg every day?
3 Have I checked temperature and pulse charts every day?
4 Have I told the patient to move his toes and his ankle joints actively *through the full range?*

5 Have I inquired every day what exercises had been carried out on the day before, how long they had lasted, and whether the patient felt comfortable in exercising or had pain?
6 Have I checked every day as to whether the splint was well-bound (see page 1183)?
7 Have I checked every day as to whether the splint was exactly level or was tilted?
8 Have I had the horse-hair mattress upholstered more tightly when the patient's buttocks sank in deeply, thus causing a tilting of the splint?
9 Have I checked every day whether the patient presses against the wooden foot-rest with the foot of the sound limb?
10 Have I checked whether the splint points to the lower end on the injured side on fractures of the upper femoral shaft and whether it lies in the long axis of the bed in fractures of the lower shaft?
11 Have I checked every day whether the point of flexion of the knee exactly corresponds to the angle of the splint in fractures of the upper shaft and whether it is 4—8 cm distal to the angle of the splint in fractures of the lower shaft?
12 Have I checked every day whether the traction cord lies in line with the long axis of the femur in fractures of the upper shaft and whether it lies close above the toes, or at a level with the metatarsus, in fractures of the lower shaft?
13 Have I checked whether the forefoot traction is in order?
14. Have I checked whether the inner side of the foot is vertical and not tilted laterally or medially?
15 Have I incised the edge of the Unna's paste bandage at the forefoot if in "cut in" any place?
16 Have I suspended the outer end of the pin from the gallows by means of a calico bandage if the leg rotated externally in spite of the forefoot traction (fig 1604 a)?
17 *Have I looked every day at the sites of pin or wire unless they were covered with a bandage?*
18 *Have I exposed the sites of pin or wire covered with bandage if the patient complained of pain?*
19 *Have I applied to the sites of pin or wire an alcohol-soaked sponge in case of incipient inflammation?*
20 Have I, if inflammation did not recede and in order to prevent spreading inflammation, removed the pin or wire after having inserted another pin or wire proximally or distally (fig 1614)?
21 Have I checked every day the amount of the traction weight?
22 **Have I reduced the traction weight immediately when the X-ray showed** a diastasis in order to prevent **the sequelae of distraction**(Vol. I/pp 25—27, and M N /pp 98—127)?
23 Have I checked whether the traction weights hung free without resting or getting caught anywhere?

24 Have I increased the traction weight when the roentgenograms showed a shortening of more than 10 mm?
25 Have I taken exactly anterior and lateral check roentgenograms on the second or third day, again after one week, and every other week later on?
26 Have I avoided too-frequent roentgenograms and manipulations?
27 Have I taken anterior and lateral roentgenograms after removing the traction weights and again at the end of the treatment?
28 Have I marked the site of the fracture to help the roentgen technician in centering the central ray?
29 Have I marked the upper and lower edges of the area to be included on the film with lines on the skin to indicate to the roentgen assistant what size film she should use and where she should place the cassette?
30 Have I afforded the patient adequate bowel care with diet and, if needed, with medications?
31 Have I had the patient's blackboard filled-in as it should be (fig 1614)?
32 Have I registered exercises and ranges of motion on the chart?
33 Have I made thorough rounds once a week, checking all notes on the patients' blackboards and charts and reviewing the whole series of roentgenograms?

Exercises and Occupational Therapy for Cases of Femoral Fractures in Skeletal Traction

Exercises During the First Week Beginning the first day, the patient must move first just his toes and then the para-talar joints *actively and through full range* This not only prevents drop-foot formation but also helps retain full joint mobility No perceptible atrophy of the crural muscles will then result, since plantar flexion in the ankle-joint is carried out against the resistance of the forefoot traction of 1 Kg and blood circulation is increased by the active motion The surgeon should check on every rounds to see whether these movements can be carried out through full range, telling the patient to repeat them several times every day if they do not cause him pain Thus, developing peroneal nerve paralysis cannot be overlooked

In the positioning described above, and with these exercises carried out, no swellings in the region of the lower leg and the ankle will appear Thrombosis and embolism are rare Moreover, the patient is told to breathe deeply and to sit upright (fig 1604 b) in order more thoroughly to ventilate the lungs With the patient in well-positioned skeletal traction, coughing ceases after a few days to cause any pain Therefore the danger of the patient's developing pneumonia is only slight As Koch[1] has pointed out, only one of our 1575 femoral fracture patients died of pneumonia That patient was in the hospital toward the end of the war and had to be carried into the air-raid shelter every day He died on his ninetieth hospital day

Most patients arranged in bed as described above have only slight pain during the first few days and then very soon become entirely pain-free

[1] Koch, F W Sind postoperative Pneumonien vermeidbar? Munchen med Wchnschr *94* 2569 2574, 1952

Muscle spasms develop only rarely in cases treated in skeletal traction, and in these cases the spasms invariably relent after a few days

By holding onto the trapeze and pressing against the foot-rest with the sound-side foot, the patient can move himself slightly in bed so that he need not always lie on the same part of his back This is usually sufficient to prevent the development of pressure sores over the buttocks and sacrum By bending the knee of the sound limb he can lift his pelvis without assistance (fig 1604 c) We are in the habit of fixing the involved thigh to the Braun splint by means of a strap so that the patient is deterred from raising or angulating that thigh When he raises that thigh he raises then the splint along with it He is able to use the bed-pan by himself and can move about well enough so that he can be bathed by just one nurse These movements are entirely painless after only a few days And they are made possible by the fact that the frictional resistance to movement of the traction cord is brought to a minimum by virtue of the cord's being passed over just one pulley and running to a free-hanging weight When the patient sits up, he moves his trunk relative to his motionless affected lower limb The knee does not bend

Exercises from the Second Week On In the second week the patient should begin to exercise the injured thigh and the sound limb

Active Thigh-muscle Contraction Beginning in the second week, the surgeon should on every rounds instruct the patient to contract the muscles of his injured thigh Some patients are able to do so at once, while others need a little time in which to learn it These latter should be shown how to contract the muscles in the sound limb and then, when they are able to do that, should be instructed to contract the muscles of both limbs at the same time and to repeat such exercises frequently This will prevent pronounced muscle wasting even in the injured thigh — something which no amount of massage can accomplish

Exercising of the Sound Limb on the Knee-Flexion Apparatus From the second week on, old and weak patients should exercise the sound limb twice each day on the knee-flexion apparatus (figs 1574, 1575) Each session should be five minutes long at first and then should be increased by five minutes each day until, after 10 to 14 days, the patient is exercising for 45 minutes twice daily More than this amount of such exercising should not be permitted If the patient becomes over-tired or has other complaints, the amount of exercising must be regulated accordingly It may even be necessary to stop it altogether for a day or so If, however, such exercises are well-tolerated they are later supplanted by exercises on the "mountain climber"

Exercising of the Sound Limb on the "Mountain-Climber" For patients who are strong and otherwise healthy one orders sound-limb exercises on the "mountain-climber" (Vol I/figs 21, 22) in the second week Here, too, exercising should be done in two daily periods beginning with five minutes for each session and increasing by five minutes each day to a total of 45 minutes twice a day provided the patient is not made uncomfortable thereby At the first session the apparatus is adjusted to lie flat on the bed, and no weights are used Later the track is made gradually steeper and the amount of weight is

increased Strong patients are able after a few days to use as much as 10 Kg with the track at maximum grade Incidentally, since the "mountain-climber" and the weights used with it are rather heavy, we had small, mobile and slightly tilted tables made which are the same height as the beds and on which the "mountain-climbing" apparatus can be relatively easily transported to and from the beds By means of these "mountain-climbing" exercises the muscles of the sound limb are kept strong and are frequently made even stronger than they were at the outset As soon, then, as the broken bone is solidly healed, these patients are fully able to bear their entire weight on the sound limb If one watches patients as they do these exercises on the "mountain-climber" one sees that not only the muscles of the limb work but that the abdominal muscles and even the sterno-cleido-mastoid muscles are called into the game And of course the heart and lungs also take part Even the injured limb — in fact, the entire body — shares in the increased circulation It is particularly interesting that the patients doing these exercises, alternately contracting and relaxing the musculature of the abdominal wall and so raising and lowering the intra-abdominal pressure, have regular daily bowel movements We have seen many elderly women patients who had previously suffered through years of obstinate constipation in the treatment of which no medical or physical measures had shown much success When, however, they were admitted with femoral fractures and began with these exercises, even they moved their bowels daily without aid

In addition to these exercises for the sound lower limb, exercises for the arms as described on page 33 of Vol I should be done beginning in the second week It is best to have these arm exercises and breathing exercises done simultaneously by all the patients in the room, and in many places they are done to music

Lying Flat Flexion contractures of the hip are avoided by having the patient lie flat at least once each day beginning in the fourth week (fig 1404 d) First the back-rest is lowered halfway and, if no shortness of breath or other complaints develop, after a few days it is lowered all the way or is completely removed. Here, too, one should begin with periods of five minutes and should gradually lengthen them to 15 minutes — a maximum which as a rule need not be exceeded As with all other exercises, this should be painless

Notation of Exercises on Blackboard and Chart Since many of the exercises and the manner of their performance are all too easily neglected, the surgeon should specifically inquire about them each time he makes rounds and should find out just what exercises are being done and for how long they are being done These things should then be entered on the blackboard and in the chart

Occupational Therapy We have most of our long-term patients do leather work or weave or knit or do something else which keeps them usefully busy With these things and the exercises they fill out their day and simply have no time for boredom An occupational therapist explains the work and distributes the material, supervising this program as the physical therapist supervises the exercise program Relative to both of these programs, the utmost importance must be accorded the dictum that *no pain* or fatigue shall result

from them And all of these things should be made really pleasant for the patient

Removal of Traction When the fracture has firmly united, the pin or wire is removed from the tibia or femur The length of the limb and the mobility of all joints are measured and the results entered in the chart

Application of Unna's Paste Boot Swelling of the leg and about the knee invariably occurs when the patient is allowed up To prevent that, an Unna's paste boot should be applied and then the knee should be wrapped during the day with an elastic bandage which is removed at night (see page 1165).

Exercising the Injured Leg on the Knee-flexion Apparatus One begins with five minutes twice a day and increases each period by five minutes each day up to a total of 45 minutes twice daily — provided, of course, this causes no pain or other trouble It may be necessary in some cases to increase the time more gradually The transverse rod of the apparatus is raised just enough to lift the heel 2 to 3 cm from the bed, and at first the patient moves the leg only by pulling it up by hand After a few days he is directed to extend the knee actively but, since full active extension is impossible, to supplement it with manual traction on the cord The younger the patient and the greater the distance of fracture from the knee joint, the more quickly will mobility increase with these exercises Knee joint mobility should be measured every week and should be entered in the chart

Walking with Quadripod Canes Two to four days after removal of the traction, the patient is allowed up with two quadripod canes (fig 1635) for support The younger patients will be able in just a few days to walk with two ordinary canes and then soon after with just one

Massage and passive motion we forbid, since massage cannot strengthen the muscles and since passive motion irritates the knee joint and causes it to swell Mobility is not thereby increased, but rather it is frequently diminished And passive motion is painful We must, therefore, especially warn against its being performed under anesthesia I have seen several cases in which such passive motion under anesthesia has resulted in fracture of the patella or in avulsion of the tibial tubercle I know of one patient whose patella was fractured twice in six months during such manipulation under cover of anesthesia

Questions We Should Ask Ourselves to Avoid Mistakes in Exercises and Occupational Therapy for Patients with Fracture of the Femur

1 Have I explained to the patient that he must from the very first day move at first just his toes alone and then his ankle joint actively through full range?
2 Have I, each time I have made rounds, instructed the patient to breathe deeply?
3 Have I told the patient from the second week on to exercise the thigh muscles of the injured limb by repeated active contractions?

4 Have I had weak and old patients begin in the second week to exercise the sound limb on the knee-flexion apparatus for five minutes each morning and again each afternoon, provided this caused no discomfort?
5 Have I extended these exercise periods by adding five minutes to each period daily up to a total of 45 minutes twice a day, provided this caused no discomfort?
6 Have I had the patient work with the "mountain-climber" during the third or fourth week so that I might know whether or not he was able to exercise regularly with it?
7 Have I stopped all exercises for one or more days if they caused pain?
8. Have I had strong and otherwise healthy patients begin in the second week to exercise the sound leg on the "mountain-climber" for five minutes each morning and again each afternoon, and have I extended these periods daily by five minutes each up to a total of 45 minutes twice a day, provided this caused no discomfort?
9 Have I had the patient use the "mountain-climber" for the first time with the rails flat and without weights?
10 Have I gradually increased the steepness of the rail and the amounts of the weights, provided this caused no discomfort?
11 Have I facilitated the handling of the "mountain-climber" by providing a small movable table on which it could be easily transported to and from the patient's bed?
12 Have I had the patient carry out arm exercises, either independently or with a group, as described in Vol I/p 33?
13 Have I had the patient lie flat in bed for five minutes a day beginning in the fourth week and for gradually longer periods up to a maximum of 15 minutes each day, provided this caused no discomfort?
14 Have I kept the patient busy with handiwork if he was interested in it?
15 Have I had the exercises supervised by a physical therapist and the occupational exercises by a trained occupational therapist?
16 Have I asked the patients each day exactly how long they exercise?
17. Have I seen to it that the type, duration and any changes of the patient's exercises be entered on the patient's blackboard and chart?
18 Have I seen to it that neither pain nor fatigue was caused by the exercises and that the spirit of fun in them was emphasized?
19 Have I measured the length of the injured limb and the ranges of motion *of all joints after removing the traction?*
20 Have I applied an Unna's paste boot up to the knee and then an elastic bandage round the knee before allowing the patient up?
21 Have I had the patient exercise the injured limb on the knee-flexion apparatus, starting with five minutes twice a day and gradually extending those periods to a total of 45 minutes twice a day, provided this caused no discomfort?
22 Have I had the patient actively extend the knee in the injured limb beginning in the second week?
23 Have I instructed the patient to supplement these active attempts at extension by pulling with his hands on the apparatus cord?

24 Have I had the patient walk with proper supports two to four days after removal of the traction?

25 *Have I strictly prohibited massage and passive motion?*

TREATMENT OF ADDUCTION OR VARUS FRACTURES OF THE FEMORAL NECK IN CONTINUOUS TRACTION WITH PIN OR WIRE

For *reduction* and subsequent *treatment* of an adduction or varus fracture of the femoral neck one needs the same things as for the treatment of a femoral shaft fracture (see page 1182)

The *clinical examination* should be carried out as described on pages 1162 and 1163

Local Anesthesia One finds the pulsating femoral artery just caudal to the inguinal ligament and then a fingerbreadth or two lateral to it inserts an 8—10 cm needle in a vertical direction until it strikes bone The point of the needle then is on the femoral head or the femoral neck — i e, within the hip joint Here one injects five cc of a 2% solution of Novocain Sometimes, though by no means always, some bloody fluid drips from the needle after the syringe has been removed from it, and in that case one should inject another 15 cc of the Novocain solution Then the sites of projected entry and exit of the pin are determined by locating the level of juncture of femoral condyles with metaphysis and these areas are anesthetized by injection of 10 cc of the 2% Novocain solution posterolaterally and another 10 cc anteromedially If the injection needle properly found its way into the hip joint, the patient should be free from pain either at once or after a very few minutes and can then be moved about as necessary for the making of good roentgenograms without significant discomfort

Roentgenograms First, two A-P roentgenograms are made, one with the injured limb in its pathognomonic position of external rotation (fig 1594) and one with it in internal rotation (fig 1595) Then follows a lateral roentgenogram, which can be made in any of three different ways (1) the injured thigh is brought up to right-angle flexion of the hip and is widely abducted (fig 1598), the central ray's being in the A—P projection and centered on the femoral neck (film size 18 × 24 cm or 8 × 10 inches), or (2) the patient is placed in the lithotomy position with both hips and both knees flexed to right angles and with the thighs widely abducted The legs rest horizontally on stands of appropriate height An A—P scout film of the entire pelvis is then made (film size 30 × 40 cm or 11 × 14 inches) with the central ray centered on the symphysis pubis (fig 1596) In such roentgenogram one sees the broken femoral neck in exactly lateral projection and has at the same time a good comparison with the sound side, or (3) one can leave the injured limb extended and externally rotated on the table, flex the sound-side knee and hip joints to right angles, and then arrange the X-ray tube and the cassette (film size 18 × 24 cm or 8 × 10 inches) essentially as shown in figures 1702 and 1702 For the making of all lateral roentgenograms of the femoral neck, the central ray must be directed in a plane which is lateral insofar as that femoral neck is concerned, for good laterals can be made in no

other way Between exposures of the roentgenograms, and after they have all been made and are being processed, the patient should be covered in order that he not become chilled

General Remarks Concerning Reduction of Femoral Neck Fractures. There are three major types of adduction or varus fractures of the femoral neck In the first of these there is external rotation of the peripheral fragment without lateral displacement or shortening In these the fracture defect is open anteriorly (fig 1643, 1647, 1667) In the second of these types there is cranial displacement of the peripheral fragment which, though it is really a "lateral displacement," in fracture of the femoral neck causes a shortening (figs 1594, 1615, 1677, 1701) Often there is associated anterior displacement of the peripheral fragment as well (figs. 1596, 1705) Very rarely the dorsal displacement of the peripheral fragment amounts to the entire A—P diameter of the femoral neck so that the head fragment comes to lie ventral to the neck and has its fracture surface directed somewhat ventrally (fig 1731) In the third type the calcar femorale of the fractured neck is displaced upward and impacted into the femoral head (figs 1601—1603, 1674)

We reduce most fractures of the femoral neck by continuous skeletal traction with a pin or wire In the first of the above types without lateral displacement or shortening one can effect accurate reduction merely by internally rotating the limb (figs 1720—1733) In the second type, in which there is upward displacement of the peripheral fragment, this shortening must first be overcome by longitudinal traction Only then can one correct the angulation (angle open posteriorly) by internally rotating the limb Usually the traction itself reduces that angulation as well as the shortening (figs 1594—1600, 1704—1707) We must not use too much traction weight lest lenghtening (fig 1599) or posterior displacement of the head fragment result In the third type, with impaction of the neck into the base of head caudally (figs 1601—1603), traction weights of from ten to twelve Kg must sometimes be used to free the head of the impacting neck (figs 1603, 1603 a).

Placing the Patient in Bed When the roentgenograms have been made, the patient is lifted over into a bed which has been previously warmed with a light cradle and his injured limb is placed on a well-prepared Braun splint (see page 1183).

Insertion of the Pin is carried out as described on page 1188 with this difference the limb should first be internally rotated 30° and the pin driven not through the tibial tuberosity but rather from anteromedially to posterolaterally through the distal femoral shaft immediately proximal to the condyles. In this way the pin will be horizontal while the limb is in the internal rotation necessary to effect reduction of the posteriorly open angle.

Application of the Perforated Felt Pads and Metal Discs As the bones are frequently atrophic in patients with femoral neck fracture, the pin or wire may slide if it is left free In order to prevent such sliding, we apply centrally perforated felt pads and metal discs on both ends of the pin before attaching the rotating stirrup and sheathing the point of the pin

Application of the supplementary splint hoop, attachment of the traction cord, arrangement of the gallows and application of the forefoot traction are done as described on pages 1189—1198 for treatment of fractures of the femur

Selecting the Amount of Traction Weight In fractures of the neck of the femur one should begin traction with only one-tenth of the body weight Ordinarily, then, only seven kilos should be used for a patient weighing 70 Kg, though 10 to 12 Kg might be required in that same patient if he had an impacted fracture

Subsequent treatment with pin or wire traction is carried out as described on pages 1200—1202 for fractures of the femur

The Trochanter-Spine-Umbilicus Line As long as there is a shortening in fracture of the femoral neck or in the trochanteric region, the extrapolation of a line drawn from the tip of the greater trochanter through the anterior superior iliac spine passes caudal to the umbilicus If traction is successful in overcoming that shortening, this line will be found to pass through the umbilicus

Applying the Rotatory Traction As soon as shortening has been overcome, the limb should be internally rotated about 20 to 30 degrees and the lateral end of the pin tied to the gallows with a calico bandage (fig 1604 a) This effects correction of the posteriorly open angle (antecurvation)

General Examination When the patient has recovered from eventual shock, one should examine the heart and the kidneys in addition to checking the pulse, the reflexes and the mobility of joints Blood pressure should be measured and blood taken for Wassermann test

The Fifteen-Second Breathing Test An extremely simple and very reliable method for simultaneous checking of the lungs and cardiovascular system is to have the patient hold his breath with mouth closed and nose pinched tightly shut The many other tests including electrocardiograms and vital capacity determinations, etc, have not for me yielded nearly such reliable results Patients with femoral neck fractures are, then, to be considered eligible for treatment by operation or in a Whitman spica only if they are able to hold their breath for at least fifteen seconds If they are unable to do that, then preliminary treatment directed toward effecting cardiac adequacy should be given

We have had many patients who at the outset could hold their breath for only five seconds but who, after three to six weeks of treatment as indicated, were able to hold it for fifteen seconds. Unless the patient can be brought to this minimum limit, one must refrain from operating on him

First Check Roentgenograms On the second day, A—P and lateral roentgenograms are made as shown in figures 1702 and 1703 For the making of the lateral roentgenogram, the sound limb should be so flexed in knee and hip joints that the foot rests on the more distal trapeze (onto which the patient shown in figure 1604 b is holding)

Altering the Traction Weight The fracture is often reduced within 24 hours If after that time shortening persists, one kilo should be added, if lengthening has occurred (as in figure 1597), the amount of weight should

be reduced If antecurvation is present, the limb should be more markedly internally rotated

Second Check Roentgenograms New roentgenograms are made on the third or fourth day If they show that the position is not yet satisfactory, weights and/or degrees of rotation are changed accordingly In the impacted adduction



1615, November 14, 1924



1616, November 15, 1924



1617, January 8, 1925



1618, February 8, 1925



1619, February 28, 1925



1620, May 26, 1925

Fig 1615—Medial, nonimpacted adduction or varus fracture four days after injury in a 53 year old woman who was knocked down by a cyclist

Fig 1616—Check roentgenogram re figure 1615 in internal rotation after longitudinal traction had been exerted for 24 hours The fragments show accurate alignment

Fig 1617—Check roentgenogram re figure 1615 after seven weeks' traction with an Unna's paste bandage Good alignment of fragments The fracture line is still visible

Fig 1618—Check roentgenogram re figure 1615, twelve weeks later The calcium content of the fracture ends has increased Slight valgus position and small gap between fragments medially Therefore longitudinal traction was reduced by one kilo

Fig 1619—Check roentgenogram re figure 1615, after 15 weeks The fracture line on the medial side is no longer visible

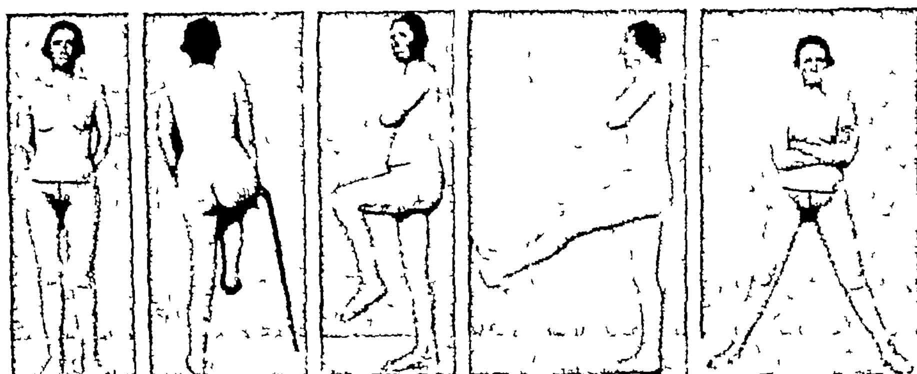
Fig 1620 Check roentgenogram re figure 1615, after six and one-half months Taken with limb in marked external rotation Bony union in good position

or varus fractures (figs 1601—1603) one occasionally needs traction weight of ten to twelve Kg to disengage the fragments

Duration of Treatment with Skeletal Traction If the general condition of the patient is good and his fracture is satisfactorily reduced, he may be operated on after two to four days in traction If his condition is poor we wait

until he can pass the fifteen-second breathing test Most of our patients with severe cardiac or other disorders have died within the first few weeks with circulatory failure, pneumonia, pulmonary embolism or cachexia After six weeks we remove the skeletal traction from those few patients who have survived without having improved sufficiently that they could pass the fifteen-second breathing test, since with them there is little chance of bony union The fracture has in the meanwhile become painless, so we allow the patients to sit up and later even to walk carefully

Figures 1615—1625 show that it is on rare occasion possible to achieve bony union in good position even with continuous traction



1621—1625, July 20, 1925

FIGS 1621—1625 —Photographs re figures 1615—1620, eight months after injury and two months after removal of the Unna's paste traction bandage All joints are freely mobile Good tonus of muscles Walks without perceptible difficulty At a follow-up examination 13 years after the injury she had no complaints, the hip joint of this 66 year old woman was freely mobile

Questions We Should Ask Ourselves to Avoid Failure in the Treatment of Adduction or Varus Fracture of the Femoral Neck with Skeletal Traction

These are the same as in the treatment of fractures of the femur (see pp 1198 and 1202) In addition, however, we should ask ourselves

1 Have I anesthetized the hip joint locally before taking the roentgenograms?
2 Have I then anesthetized the metaphyseal region locally for the anteromedial and posterolateral points of entry and exit of the pin?
3 Have I taken three roentgenograms, viz , two in the A—P projection with the limb first in the position of deformity (external rotation) and then in forced internal rotation, and lastly one in the lateral projection?
4 Have I directed the central ray for the lateral view so that it parallels the "coronal" plane of the injured femoral neck?
5 Have I covered the patient to prevent chilling both during and immediately after taking the roentgenograms?
6 Have I driven the pin through femoral metaphysis rather than through the tibial tubercle?

7. Have I driven in the pin with the limb in internal rotation so that the point of entry is anteromedial and the point of exit posterolateral?
8. Have I avoided driving the pin through the femoral diaphysis, lest a large piece of cortex might be broken out?
9. Have I put perforated felt pads and metal discs on both ends of the pin or wire to prevent its migration?
10. Have I applied only one-tenth of the body weight for the longitudinal traction?
11. Have I checked the trochanter-spine-umbilicus line a few hours after applying the traction?
12. Have I rotated the limb internally about 30° as soon as the trochanter-spine-umbilicus line actually passed through the umbilicus and so indicated any shortening to have been overcome?
13. Have I given the patient the fifteen-second breathing test in addition to the general physical examination?
14. Have I taken A—P and lateral check roentgenograms on the second day?
15. Have I then increased the traction weight if those roentgenograms showed shortening and decreased it if they showed lengthening?
16. Have I removed the skeletal traction after six weeks from those patients not fit for operation?

TREATMENT OF ADDUCTION OR VARUS FRACTURES OF THE FEMORAL NECK WITH THE WHITMAN PLASTER SPICA

The large Whitman thoracopelvic hip spica should be applied only to patients whose general condition is good. Because of the heavy burden this spica imposes on the patient, it should not be used in patients suffering from cardiovascular, pulmonary, renal or prostatic diseases or affections nor in those patients with tabes or metastatic tumor It is likewise contraindicated in patients who were bed-fast before the injury and in those who are markedly obese It should be reserved for use in those patients whose general condition is such that one can reasonably expect them to be able to walk with the spica within four weeks after its application We use it rarely now, since we treat most fractures of the femoral neck by operation.

For the *reduction* and Whitman spica *immobilization* of adduction or varus fracture of the femoral neck are required.

1. Two A—P roentgenograms, one with the limb in the externally-rotated position of deformity and one with the limb internally rotated, and a single lateral roentgenogram (figs 1594—1596),
2. A pelvic support (fig 1576),
3. A support for the head and thorax (fig 1576) A bolster of suitable size can also be used;
4. A screw-traction apparatus (Vol. I/figs 103—105, fig 1577) or some other suitable traction apparatus,
5. Two foot-slings (figs 1577, 1626),
6. If no traction apparatus is available, two small adjustable instrument tables (figs 1627—1634),

7 Local anesthesia (Vol. I/p 118, Vol. I/fig 152),
8 Two stitched cellulose pads, 0.5 × 10 × 18 cm, for both anterior superior iliac spines and iliac crests (figs 1576, 1627 and 1630),
9 One stitched cellulose pad measuring 2 × 20 × 30 cm for the sacrum and vertebrae (figs. 1576, 1627),
10 A wadding pad 45 cm long and about 2 cm thick sewn into a 15 × 230 cm calico bandage,
11. A stitched cotton-wool pad, 0 5 × 15 × 100 cm, for the thorax (fig 1630),
12 Two 15 cm × 10 m calico bandages,
13 A 15 × 15 centimeter waterproof sheet to cover the pubis;
14. A 8 × 65 centimeter flannel strip for the thigh;
15 A 5 × 35 centimeter flannel strip for the lower leg,
16 Skin adherent (e g, Mastisol),
17 Swabs for applying the skin adherent,
18 A roll of sponge rubber or cellulose measuring 40 cm in length and 7 cm. in diameter with which to protect the sternum,
19 Two rolls of sponge rubber or cellulose 24 cm long and 7 cm in diameter for padding the posterior aspect of the heel (fig 1634) and the knee,
20 Ten to twelve 17-thread plaster bandages measuring 20 cm × 5 M. and weighing about 600 Gm,
21 Eight 17-thread plaster bandages measuring 15 cm × 5 m and weighing about 450 Gm (Vol I/p 115), and finally
22 Two assistants are needed, one to pass the plaster bandages to the surgeon and prepare and pass the splints and the other to smooth the applied plaster If no traction apparatus is available, another two assistants are needed to hold the limbs (figs 1627—1633)

Preparation and Checking of Material When one plans to apply a thoracopelvic hip spica, one should order everything prepared according to the list on pages 1214, 1215 and should then check all of the material for completeness and condition Items 2—5 are placed on the operation table; everything needed for administration of the local anesthesia is placed on one small moveable table and items 8—19 are placed on another of the same kind The plaster bandages are placed on the plaster cart or table

How to Make Stitched Cellulose Pads A cellulose pad of the desired thickness is cut to the proper size, wrapped in calico and the two stitched together With such pads one can provide even and constant padding, while if one applies cotton-wool or cellulose directly without first sewing it into calico it will soon become fuzzy and frayed and pressure areas will develop

How to Make Sponge Rubber Rolls A piece of sponge rubber 2 cm thick and 20—40 cm long is rolled up tightly and then vulcanized This roll is then covered by sheet rubber which is made water-proof by vulcanization So-called "water-proof" cloth should not be used for this covering, since water can penetrate through the stitch-holes in cloth and cause rotting

Placing the Patient in the Screw-traction Apparatus We treat all fractures of the femoral neck first with pin or wire traction (see page 1209). As soon,

then, as ıeduction has been accomplished, the patient is taken to the room in his bed and with uninterrupted traction The feet and ankles are padded and then the foot-slings are applied (fig. 1577) After having hung the roentgenograms for convenient inspection, we then place the 2 × 20 × stitched cellulose pad on the pelvic support and lift the patient over it and onto the support for head and thorax Both lower limbs are held in wide abduction as possible, are internally rotated and are attached to the f plates (fig 1626)

Arrangement of the Patient Without Traction Apparatus The position of the patient on the supports for pelvis, thorax and head is the same as w a traction apparatus is available. The lower limbs are supported in wide duction and internal rotation on two portable instrument stands and are l so by two assistants (fig 1627)

Roentgen Control When the patient has been properly placed in g position, A—P and lateral check roentgenogıams are made For the A projection the central ray should be exactly vertical and should be cente directly over the femoral head For the lateral projection the X-ray t should be just medial to the sound-side knee (figs 1700—1702) and the cass should be very firmly pressed into the soft-tissue just above the crest of ilium and held with its longer dimension paralleling the femoral neck with its shorter dimension vertical

Application of the Padding If the roentgenograms in both projecti show the reduction to be satisfactory, we then paint the regions of the antei superior iliac spines with skin adherent and place the 0 5 × 10 × 18 stitched cellulose pads so that they cover the iliac crests and anterior supei iliac spines but so that the greater part of each pad is caudal to those bc prominences The wadding roll is put over the adductor region and distal the ischial tuberosity, and its two calico-bandage ends are then tied under "sick-side" axilla and then again over the sound-side shoulder The 0 5 15 × 100 cm stitched wadding pad is placed round the thorax just caudal the axillae and the two ends sewn together The 40 cm long by 7 diameter sponge rubber roll is put over the sternum to prevent compress of the thorax with application of the cast — or, rather, to allow for it — a to avoid the eventual necessity for splitting that part of the cast We co the pubic region with a 15 × 15 cm waterproof sheet so that the hair d not become incidentally incorporated in the plaster (fig 1630) Then the t calico bandages 15 cm wide are used to encircle and secure all of these pa the bandages being carried nearly to the knee (fig 1630)

Application of the Thoraco pelvic Part of the Cast When the padd has been applied, five 17-thread plaster bandages 20 cm wide are used encircle the thorax, abdomen, pelvis and thigh down to the vicinity of t knee The plaster should not be extended quite as far as the end of the cal bandages securing the padding and so is prevented from touching the sk Then three plaster splints 1 M long are prepared from a sixth plaster banda on a table with a hard, smooth top (we use a heavy glass-top table) and a put round the pelvis The first splint should begin at the anterioı superi

spine on the sound side, then be carried posteriorly over the sacrum to greater trochanter on the sick side and finally to the anteromedial aspect of the sick-side thigh The second splint also begins at or near the anterior superior spine on the sound side but is then carried anteriorly over the abdomen to

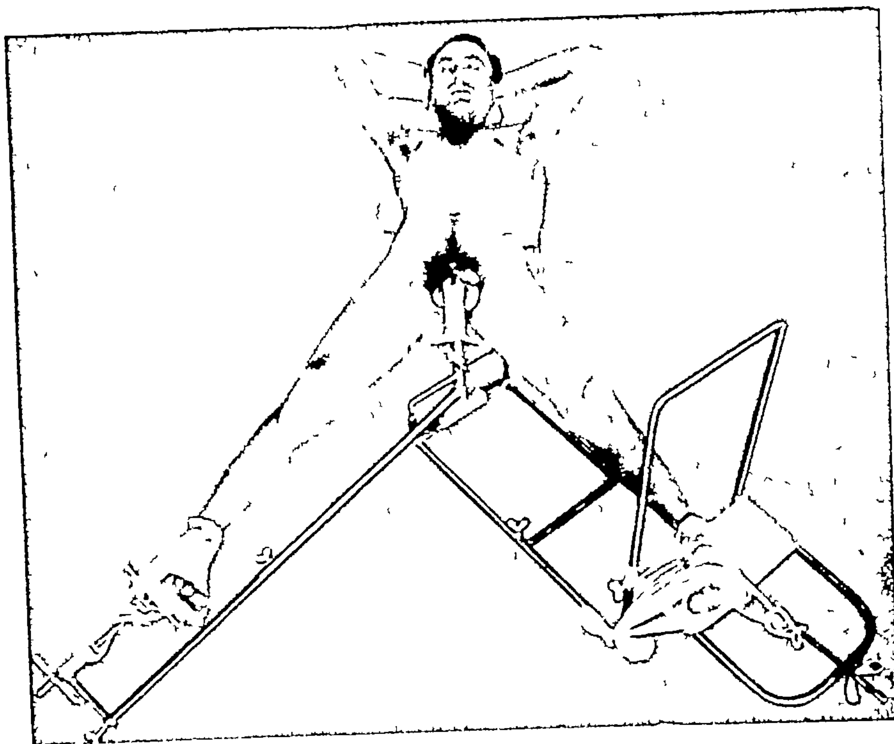
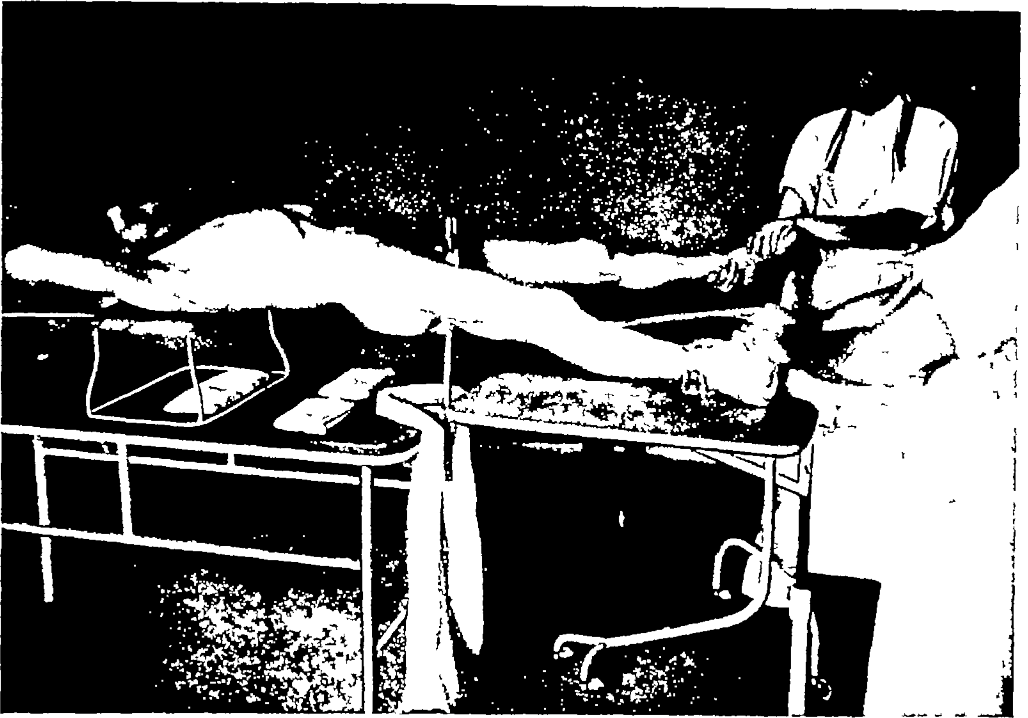


Fig 1626—Position of patient with medial adduction or varus fracture of the right femoral neck for application of the Whitman thoracopelvic hip spica on the screw-traction apparatus The patient lies on the pelvic rest and the support for thorax and head Both lower limbs are rotated internally 40° and abducted 40° Often 50° to 70° internal rotation is necessary to correct the anterior angulation The injured limb is fastened to the foot plate, the sound limb is fixed to the hook of the screw with the foot on a bandage wound round rods of the traction appliance A second bandage is put round the forefoot to retain the internal rotation At present we also fix the sound-side foot to a foot plate

the greater trochanter on the sick side and then down around the sick-side thigh to its posteromedial aspect The third one-meter plaster splint is then divided transversely into three equal parts, the first of which is put on the lateral side of the hip region in the direction of the long axis of the body and the remaining two of which are applied diagonally on the ventral and dorsal aspects of the hip region and distally enough so as to allow the posterior one to cover most of the sick-side buttock (figs 1578—1580) Then, depending upon the size of the patient, two to four of the plaster bandages are applied round the thorax, abdomen, pelvis and thigh

Modeling or Molding the Cast As the plaster is applied its surface should constantly be lightly rubbed by the flat of the hand and the thumb so that it comes to conform to the body contours above and below the iliac crests round the trochanter and about the ischial tuberosity The trochanter should



April 28, 1931

FIG 1627—Position of patient with medial fracture of the neck of the femur on the pelvic rest and the support for the thorax and head The pads, except the sponge rubber roll for the sternum, are prepared on the table Each limb is placed on a small table so that they remain at the same height and so that holding them is not so fatiguing for the assistants Under strong traction, both limbs are abducted as much as possible and both are rotated internally to the same degree



FIG 1628—If, in spite of internal rotation, there remains an angle open posteriorly, we flex the knee joint to a right angle and rotate the thigh internally under persistent longitudinal traction Traction, abduction and internal rotation should be applied to the sound limb in the same degree as to the injured one to avoid twisting of the pelvis The sound knee should, therefore have been flexed at the same time.

be surrounded anteriorly by a horseshoe-shaped depression which opens posteriorly beneath the ischial tuberosity (figs 1632, 2081 and 2082)

Adding the Knee Part of the Cast Having completed the above, we put the 5-cm-wide felt strip round the lower part of the leg proximal to the



FIG 1629 – Impaction of the femoral neck, no longer practiced by us

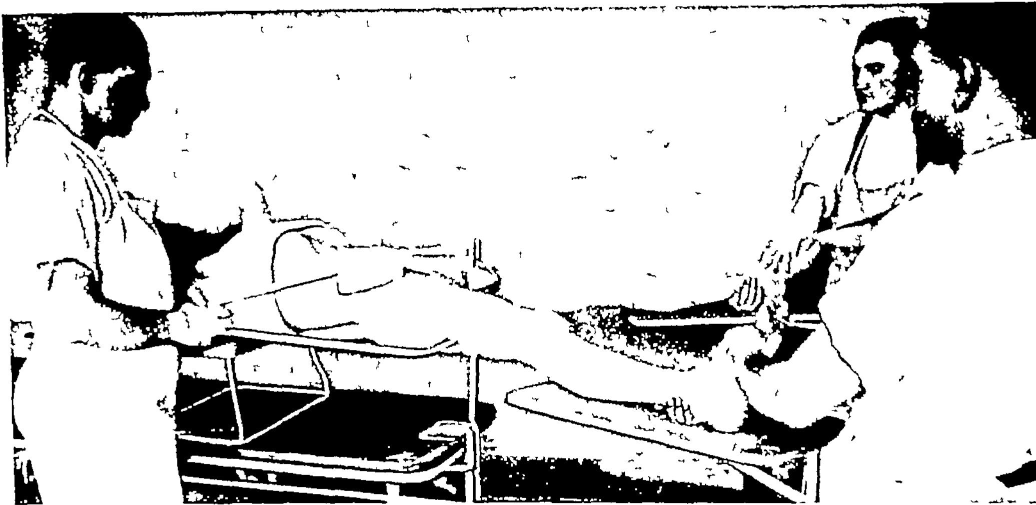


FIG 1630 —The pads for the chest, for the sacrum and vertebrae and for the crests of the ilia are in position An assistant is pulling firmly on the roller-shaped pad for the ischial tuberosity and adductor region It would be better still to tie the two slings crosswise under the axilla of the injured side and then over the shoulder of the sound side The sponge-rubber roll for the sternum is not shown

ankle Then a 60 to 80-centimeter-long plaster splint is made from a couple of the 15-centimeter-wide plaster bandages and is put on the dorsal side of the limb from the ankle to the hip, the knee being held in full extension It is important that the knee be *neither flexed nor hyperextended* We then secure that plaster splint with two encircling plaster bandages, after which the region of the knee is reinforced by three splints 25 cm long, one applied anteriorly

and the others laterally and medially Finally, two more plaster bandages are circularly applied The plaster must *not* be molded about the femoral condyles, the tibial plateaux and the patella (fig. 1633)

Adding the Foot Part of the Cast As soon as the knee part is finished and firm, the foot slings are removed and the region of the knee is supported by a rubber roll on a small adjustable instrument table Then a plaster splint

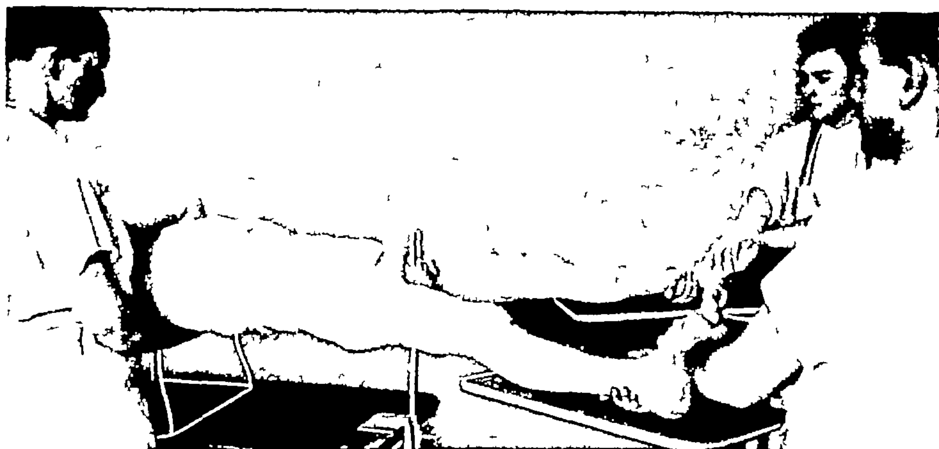


FIG 1631 —The five pads have been securely bound in place by a calico bandage

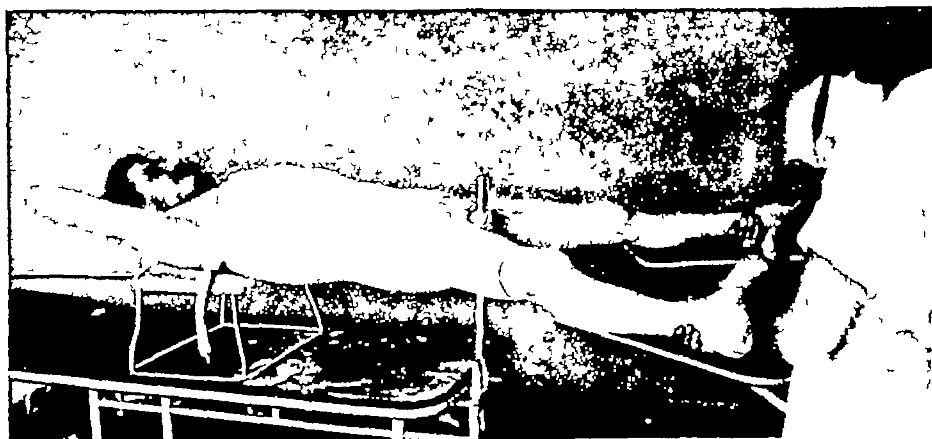


FIG 1632 —First stage the thoracopelvic part of the plaster cast

50 cm long is applied posteriorly beginning at the middle of the calf and continuing round the sole of the foot to a few centimeters beyond the ends of the toes Darts are cut into both sides of the plaster splint at the point of the heel and the edges so formed are placed very carefully one over the other so as to avoid wrinkles in the plaster We then secure the splint with a circularly applied gauze bandage, the ankle being in slight flexion (95° to 100°) The part of the splint extending beyond the toes is then folded back so that plaster extends just to their tips, and two plaster bandages are wound evenly round leg, ankle and foot and carried on the dorsum of the foot as far as the webs of the toes It must not be carried farther, since the patient must be able to move the toes and we must be able to see them in order to check on the

adequacy of circulation in the limb It is, of course, equally important that the plaster not stop short of the webs of the toes, since in that case an edema develops in the dorsum of the foot distal to that plaster border If, then, the plaster be shortened still further, the edema is not relieved but simply advances proximally to the new border And pressure sores may develop if this is not corrected in time The only remedy in such a situation is to extend the plaster

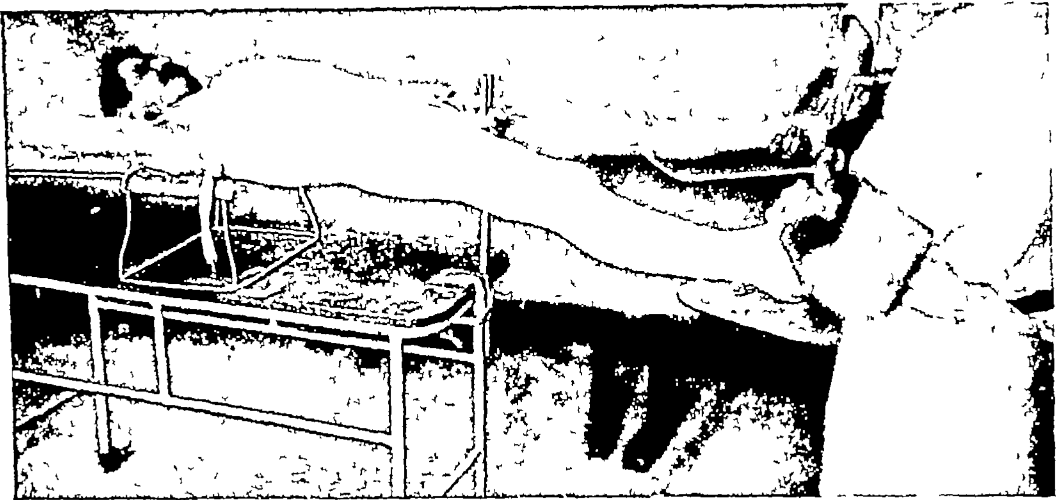


FIG 1633—Second stage the thigh and the lower leg have been included in plaster

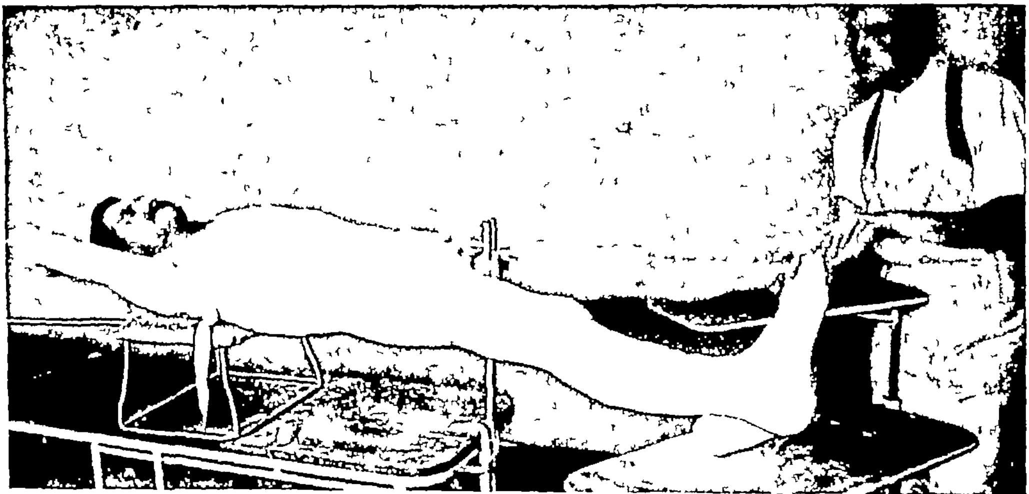


FIG 1634—Third stage the foot part has been finished The extensor surface of the toes remains exposed The Achilles tendon region is padded with a cellulose or sponge-rubber roll to protect the soft plaster from pressure indentation that might later cause a pressure ulcer

rather than shorten it, bringing the border down to the webs of the toes where it belongs We also slip a finger round between forefoot and the encircling plaster edges while the plaster is still soft so as to avoid areas of unevenness which might later cause uncomfortable pressure The finished plaster spica weighs from nine to ten Kg

Removal of the Sponge Rubber Roll from Over the Sternum While the plaster is still soft, the sponge rubber roll over the sternum is pulled out and the bulge remaining in the plaster is smoothed out

Trimming of the Cast As soon as the foot portion of the cast is finished, a roll of cellulose or sponge rubber is placed under the region of the tendo achilles (fig 1634) in order that the heel-portion of the plaster not bear the weight of the cast until it is entirely hardened Otherwise the plaster over the point of the heel might be impressed slightly and a pressure sore might result. Then we cut a window anteriorly in the thoracoabdominal region, the lower border of which must not be brought caudal to the umbilicus in order that the pelvic part of the cast not be weakened The edge of the plaster over the sound-side groin is cut away enough to allow flexion of the hip to more than a right angle (figs 1635, 1637, 1639) This is important, since otherwise the patient would be unable to sit The upper edge of the cast is then cut away so as to allow entirely unrestricted motion of the arms Among other things, the patient must be able to clean himself after moving his bowels The loose ends of the perineal pad are then cut off a hand's breadth from the edge of the cast, folded back round that edge and secured there with adhesive plaster Then the patient is turned onto his abdomen and the upper and lower plaster borders are trimmed posteriorly The plaster must not be left with a sharp edge beneath the ischial tuberosity The plaster about the ischial tuberosity must not be sharply cut away leaving an abrupt edge, but rather a small "seat" should be fashioned there beneath the tuberosity pad Over the buttocks posteriorly the plaster should not be cut away more than one to two finger-breadths from the internatal cleft (figs 1636, 1638, 1640) If one cuts away more, the soft tissues bulge out and cause pressure against the edge of the cast with consequent development of blisters and pressure ulcers Should one receive a case in which pressure areas had already developed, the open sores should be covered with ointment dressings which should in turn be covered by a cotton-wool pad The whole is then supported by a plaster splint so applied as to reduce the size of the cut-away area (figs 1578—1580) All plaster edges should be trimmed away obliquely on the skin side

Roentgenograms Anteroposterior and lateral roentgenograms are made after the plaster cast has been finished The lateral projection is sometimes technically difficult when the patient is in such a cast

Attention to the Circulation When one applies a plaster cast only after several days of preliminary treatment in traction, circulatory disturbances subsequent to application of the cast occur only rarely During the first two days after application of plaster, however, one should be aware of the possibility of circulatory disturbances in every case If there is pain and the toes swell, the plaster in its entire length must be split right through to the skin. One cannot wait until the toes turn blue and mobility and sensibility diminish. Moreover, not a single strand of plaster-bandage or padding should be left intact in the course of the split, since even a single strand may cause circulatory trouble With this meticulous splitting of the cast one provides for adequate circulation and yet holds the fragments adequately How one can

avoid the dangers associated with these circulatory disturbances and how one can make the nursing staff keenly aware of such dangers is described in detail in Vol I/pp 123 and 124 If one holds to these rules, no gangrene of the lower limb will ever be caused by a plaster cast

Drying of the Plaster Cast and Smoothing of its Edges The plaster sets in ten minutes and dries in 24 hours We use a light-cradle for several hours in order to speed up this drying On the following day we pull tight the two slings of the perineal pad and secure them with a small plaster slab Then the edges of the cast are smoothed off and are trimmed with adhesive-tape strips or with tiny Cellona strips

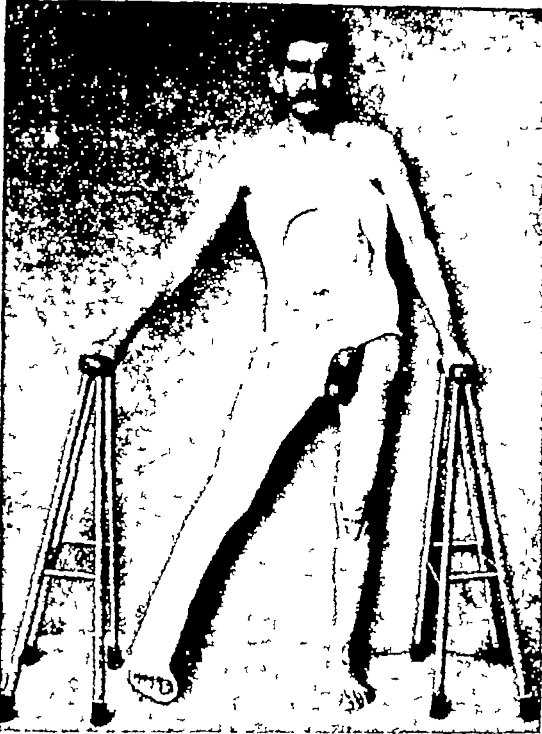
Inscription of the Plaster Cast A sketch of the prereduction roentgen findings is made on the cast over the fracture site, and below that are written the dates of injury, reduction and the next roentgenogram as well as the name of the responsible surgeon It is perhaps better in these cases to omit the date of intended removal of the plaster in order that the patient not be unnecessarily disturbed by thoughts of the long period of treatment

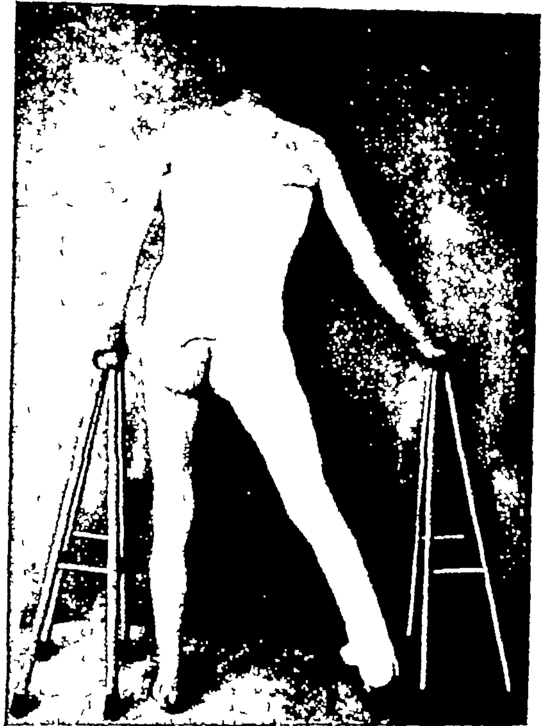
Exercises From the first day on, the toes must be actively moved through as wide a range as is painlessly possible After two or three days, when the patient has become accustomed to the huge cast, a walking-iron is applied Then he can begin walking, first with two "quadripod" canes (figs 1635—1638) for support and later with two ordinary canes (figs 1639, 1640) A three to eight cm lift should be put on the sound-side shoe in order to make walking easier (figs 1637—1640) If despite this the involved side slides sideways with weight-bearing, a second walking iron is applied, this one in the sagittal plane (fig 1639, 1640) Walking is difficult in the first week but it usually improves rapidly After six weeks in his cast, the 45 year old man shown in figures 1639 and 1640 was able to come for his clinic visits by street-car and alone If at first the patients have trouble in walking, we have them strengthen the sound limb by using the "mountain-climber" (Vol I/figs 21, 22) In addition they take part in the general group exercises, in their case with emphasis on vigorous full-range arm exercises (Vol I/p 33)

Roentgen Follow-up A-P and lateral roentgenograms should be made every four weeks If they show displacement of the fragments to have occurred, it is useless to leave the patient in the cast In such a case one should either do another reduction and apply another cast, or operate, or give up the attempt to get bony union I have seen re-displacement in plaster only when the cast was too short, i. e , when it did not extend to the axilla on the sound side

Duration of Immobilization As a rule, the large plaster cast must be left on for six months If it is removed too early the fragments re-displace and varus deformity or pseudarthrosis results

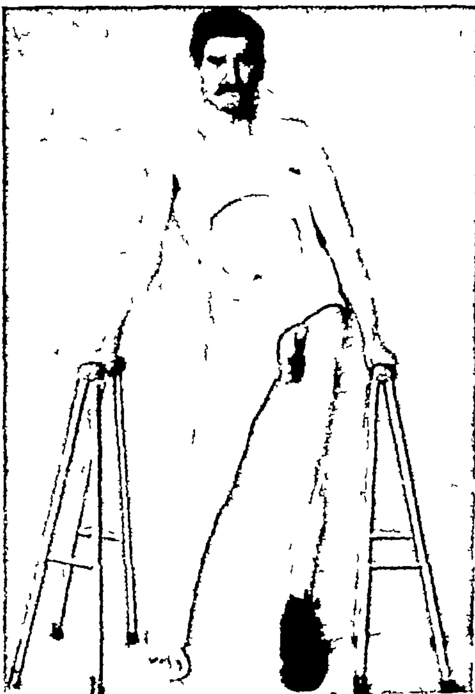
Inadequate Plaster Casts. If the cast is not applied with the limb in extreme abduction and if it does not extend well up into the axilla on the sound side (figs 1641, 1642) it later slips up on that side and the fragments re-displace because some of the abduction is lost Until 1929 I applied these casts as shown in figure 2081. I was under the false impression that I was treating the patients according to the method of Whitman and was very

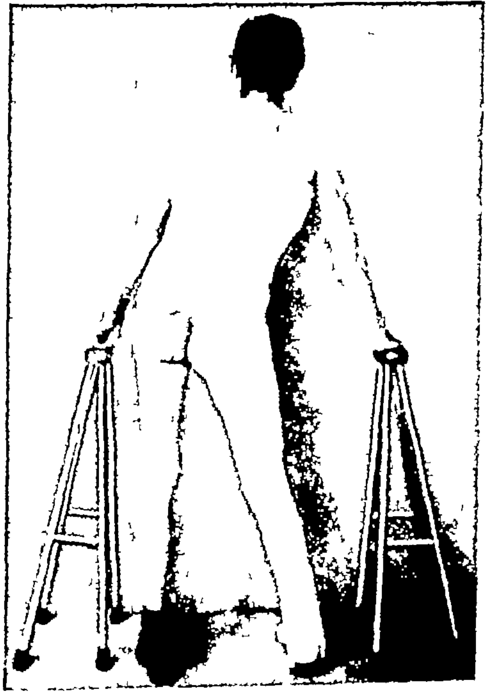




1635 1636

Figs 1635, 1636 —Well-molded plaster cast from in front and behind It is important to mold the cast between the greater trochanter and the crest of the ilium so as to prevent an upward displacement of the femur A large window has been cut out over the abdomen This one is too large, since the umbilicus is visible A walking caliper is applied to the foot The original roentgen findings are sketched over the site of the fracture The following data are marked on the cast date of injury, date of reduction, date of application of plaster cast, date of proposed check roentgenogram and the name of the surgeon The patient is provided with good quadripod canes the two legs on the inner side are vertical, the two legs on the external side are oblique In all fractures of the upper shaft of the femur treated in plaster we apply such a plaster cast but without internal rotation



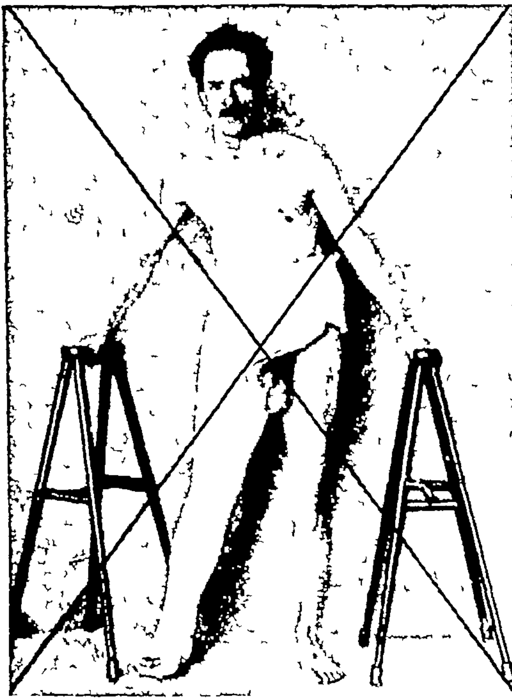


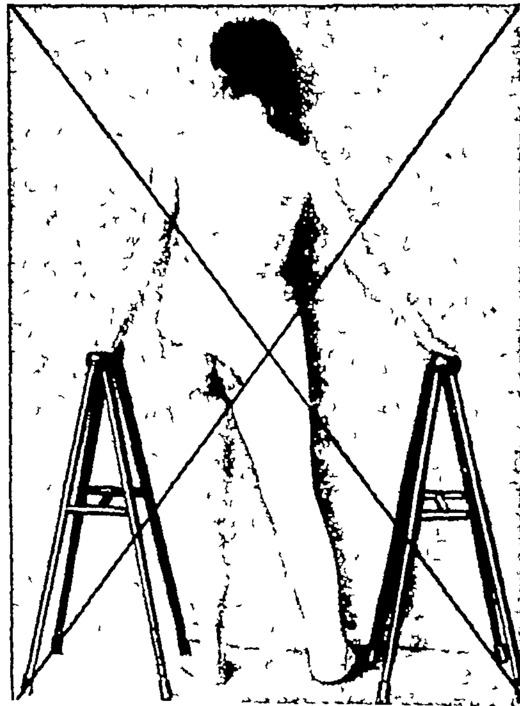




1639 1640

FIGS 1639, 1640—Medial fracture of the femoral neck with a well-molded cast A second walking caliper has been applied to the inner side of the foot, because in the strongly-abducted position the foot slipped laterally when the patient tried to walk in spite of the raised shoe on the sound side With this appliance, then, he was able after three weeks to walk a good distance He could even get into the trolley to come for his clinic visits to the out-patient department He walked with sticks only, not with quadripod canes





1641 1642

FIGS 1641, 1642—Unsuitable, thickly-padded plaster spica without walking caliper used for treating a medial fracture of the femoral neck It extends only as far as the costal margin, so that it has slipped upwards on the sound side Because of this the fragments become displaced and non-union results Note the poor quadripod canes with *oblique* legs on both sides They force the patient to hold his arms far from the body to avoid striking the canes

surprised that in many of them no bony union occurred However, after I learned of my mistake I began following Whitman's directives strictly, and since then nearly all of the femoral neck fractures treated in plaster have united, as shown in the table on page 1230

Plaster casts such as are shown in figures 1641 and 1642 are entirely inadequate In such a cast there is certain to be re-displacement of the fragments and persistent pain at the fracture site

Further Treatment After Removal of the Plaster Cast When we remove these casts after six months we are often surprised to find that those patients who have walked diligently during their whole time in plaster are at once *able to move their ankle joints actively through full range* and *to lift the affected limb with the knee joint extended* Knee-joint mobility is usually limited to only 10° to 20°, but flexion in both the knee joint and the hip joint increases to about 90° Baking and diathermy speed up this increase in joint mobility in some cases Further treatment is the same as that carried out in cases of femoral shaft fracture after removal of the traction (see page 1207)

Vigorous Massage and Forced Passive Motion Vigorous massage and passive motion have been recommended in femoral neck fractures as in all others. To my knowledge, not a single case so treated and with roentgenograms showing bony union has yet been published Passive motion causes redisplacement even of fragments which had been accurately reduced, and it repeatedly interrupts the immobilization necessary for healing As in fracture of the carpal scaphoid, friction caused by motion of the fragments leads to increased bone resorption and to non-union

Stimulants to Callus Formation Substances and media calculated to stimulate callus formation are by some surgeons used particularly enthusiastically in cases of femoral neck fracture. Calcium, Vigantol, Phosphorlebertran, preparations of thymus gland, egg-shells and fresh vegetables are given in fancy variety In addition, artificial sunlight, diathermy, short-waves, X-rays, etc are recommended All of these are just timetakers which never attain their goal, viz, bony union of the fragments

Questions We Should Ask Ourselves to Avoid Failures in Treating Adduction or Varus Fractures of the Femoral Neck with the Whitman Thoracopelvic Hip Spica

1 Have I ordered all the material listed on page 1214, and have I checked it for completeness and quality?
2. Have I used the large Whitman spica only on patients in good general condition?
3 Have I avoided using the Whitman spica in patients with cardiac, vascular, pulmonary, renal and prostatic disease, as well as in those with metastatic tumor?
4 Have I avoided using the Whitman spica in tabetic patients, on the grounds that in such cases bony union is doubtful and since, because of disturbances of innervation, pressure ulcers develop easily?
5 Have I applied the Whitman spica only after accurate reduction?

6 Have I abducted and internally rotated both limbs as far as possible before applying the spica?
7 Have I had A-P and lateral roentgenograms made before applying the spica?
8 Have I placed pads below the iliac crests and the anterior superior iliac spines, over the ischial tuberosity and about the thorax (fig 1630)?
9 Have I, after applying the other padding, put a sponge-rubber roll measuring 40 cm in length and 7 cm in diameter over the sternum?
10 Have I fixed all pads from the thorax down to just above the knee with two calico bandages of 10×15 cm (fig 1631)?
11 Have I applied the plaster splints far enough distally on both the anterior and posterior sides of the hip (figs 1578—1580)?
12 Have I molded the cast well round the ischial tuberosity?
13 Have I applied the spica with the knee joint in full extension, neither flexed nor hyperextended?
14 Have I removed the sponge-rubber roll from over the sternum after completion of the spica?
15 Have I taken A-P and lateral roentgenograms after completion of the spica?
16. Have I trimmed the edges of the cast so that the inner edges are adequately beveled-off?
17 Have I seen to it that the abdominal window is not too large, that its inferior border is not caudal to the umbilicus and that the arms can be moved unrestrictedly?
18 Have I seen to it that the plaster is not cut out too far over the buttocks (figs 1578—1580)?
19 Have I marked the spica correctly and adequately (sketch of original roentgenogram, date of injury, date of reduction and casting, date of proposed roentgen follow-up, and the name of the surgeon)?
20 Have I paid attention to the circulation and split the cast if pain increased?
21 Have I allowed the patient up after two to four days?
22 Have I applied a lift to the sound-side shoe?
23 Have I applied a second walking caliper (vertical) if the cast slipped with weight-bearing despite the raised sound-side shoe (figs 1639, 1640)?
24 Have I made follow-up A-P and lateral roentgenograms after four weeks?
25 Have I removed the spica if the roentgenograms showed redisplacement of the fragments?
26 Have I, after rereduction, applied a new plaster spica or operated on the patient?
27 Have I, if the roentgenograms showed good position and alignment of the fragments, left the plaster on for a sufficiently long time, i e, for six months?
28 Have I taken A-P roentgenograms with the limb in internal and external rotation as well as a lateral roentgenogram, after removal of the spica?
29 Have I had the patient do the exercises as discussed on page 1207 after removal of the spica?

30 Have I avoided using massage and passive motion?
31 Have I, at the completion of treatment, taken new A-P roentgenograms with the limb in internal and external rotation as well as a lateral roentgenogram?



1643, November 14, 1929



1644, April 9, 1930



1645, March 23, 1937



1646, March 23, 1937

FIG 1643 — Check roentgenogram of a medial, subcapital, intracapsular adduction or varus fracture of the femoral neck, sustained by a 54 year old woman who had fallen on the street The head of the femur had been twisted downwards out of the acetabulum, i e, abducted The shaft of the femur is rotated externally round its long axis, is adducted and has slipped cranially There is an angle between the fragments open medially and posteriorly

FIG 1644 — Check roentgenogram re figure 1643, after 5 months The fragments were reduced under local anesthesia and immobilized with the large plaster cast extending from the axillae to the tips of the toes and with the limb in extreme abduction and in internal rotation With this cast the patient was able to walk two weeks after the injury Upon removal of the cast, the alignment was found to be good but bony union had not yet occurred Therefore the patient stayed in bed for one month, receiving during that time treatment with exercises on the knee-flexion apparatus for the injured limb and on the "mountain-climbing" apparatus for the sound limb Four weeks later the hip and the knee could be flexed to 90° She got up at this stage and walked with quadripod canes Three months later she was able to walk without a stick

FIG 1645 Check roentgenogram re figure 1643, after seven and a half years The femoral head shows good position and normal structure

FIG 1646 – Check roentgenogram re figure 1645, in lithotomy position The femoral neck is of normal length and shows no angulation All joints can be actively moved through full normal range The patient is free from complaint



1647, March 13, 1929



1648, March, 28, 1929

FIG 1647 —Recent medial adduction or varus fracture of the femoral neck with comparatively slight displacement sustained by a 62 year old woman in a fall

FIG 1648 —Check roentgenogram re figure 1647, after five and one-half months, immediately after removal of the plaster cast Owing to the fact that the cast extended only to the costal margin (figures 2081, 2082) and not to the axilla, the fragments have become displaced and non-union has resulted The femoral head is evenly sclerosed, whereas the calcium density of the surrounding parts is reduced The shape of the head is well preserved The width of the joint space is normal This is the most frequent form of non-union



1649, November 3, 1934



1650, December 10, 1937

FIG 1649 —Check roentgenogram re figure 1647, after five and one-half years The lateral and caudal margins of the femoral head are sclerosed, while the femoral head itself shows almost normal density The caudal margin of the femoral head and the joint space are irregular and blurred The femur has slipped cranially and the lesser trochanter is propped against the femoral head

FIG 1650 —Check roentgenogram re figure 1647, after $8^3/_4$ years The density of the femoral head has become a great deal more irregular The caudal part of the joint-space has completely vanished The spur by which the lesser trochanter is propped against the femoral head has increased Distinctly sclerosed bone-ends, established non-union Mobility severely reduced Pain on walking Patient walks with a stick

End-results of Treatment of Medial Fractures of the Femoral Neck by means of Traction or the Whitman Thoracopelvic Spica

In order to determine in what way the end-results in fractures of the femoral neck were affected by the type of fracture, the age of the patient, the method and time of reduction, the method of immobilization and nature of subsequent treatment, I asked Stohr[1] to review the 27 fresh fractures of the femoral neck treated by me from 1926 to 1931 Of these 27 cases, two died during treatment and three died after treatment had been completed but before the study was done One patient could not be located, and one simply sent his roentgenograms and the report that he had no complaints The remaining 20 patients, representing injury-to-study time intervals of from two to eight years, were then reviewed by Stohr and me together according to a detailed plan Roentgenograms with the limb in internal and external rotation and with the patient in the lithotomy position were also made In order then that the report relative to them be objective and factual and verifiable by anyone at any time, the roentgenograms made before reduction and at the completion of treatment in all of the 27 cases were reproduced in Stohr's paper

In some statistics the firmly impacted abduction or valgus fractures, which always heal by bony union, are not distinguished from the adduction or varus fractures, which are usually not impacted and which are so difficult to treat Those statistics often indicate only whether or not bony union occurred In the few roentgenograms usually published with such reports one often sees cases of pseudarthrosis *described as bony union on the basis of A-P projections* with the limb in external rotation (figs 1663—1814) But even bony union does not always mean perfect function, since necrosis of the femoral head, bringing severe limitation of motion and pain, may develop despite union (figs 1589—1593, 1667—1673) We therefore reported the mobility of all joints from toes to hip in all the reviewed cases Walking ability was also noted, and the limb-lengths were measured

The *results* of this review are indicated by the following table

Type of Fracture	Number of Cases	Bony union		Non-Union		Died Before End of Treatment
		Joints freely mobile No shortening	Limited motion or shortening	Fibrous union	Complete non-union	
Abduction fractures	7	6	1	—	—	—
Adduction fractures	20	5	5	6	2	2
Total	27	11	6	6	2	2

[1] Stohr Mediale Schenkelhalsbrüche und ihre Ergebnisse bei konservativer Behandlung, Arch Orthop u Unfall-Chir *36* 143-178

Impacted Abduction or Valgus Fractures Bony union occurred in all seven cases Necrosis of the femoral head supervened in one case (figs 1589—1593) after initial well-being one and one-half years after the accident On the average the patients started walking eight days after the accident and left the hospital 27 days after the accident

Adduction or Varus Fractures Of the 20 patients with adduction fractures, two died before the end of treatment Among the 18 survivors there were ten cases of bony union, eight cases of non-union and seven cases of nutritional disturbances of the femoral head Average hospital stay was 148 days (whereas in operated cases it dropped to 26 days) At first, too short a plaster cast (fig 2081) was applied, and all those cases resulted in non-union Later on the larger plaster cast was applied with the limb in strong abduction and internal rotation (fig 1635), and all subsequent cases healed with bony union except for that of one tabetic female

The six patients with firm non-union (figs 1647—1666) could walk fairly well 5 to 8 years later, while the two patients with complete and loose non-union walked with severe limps

Out of a total of 25 patients surviving with femoral neck fractures, bony union occurred in 17 (68%)

Lofberg has published what is so far the largest series of cases of medial fracture of the femoral neck treated by any one surgeon himself, viz, 164 cases Six per cent of those patients died Among the survivors, results of treatment were "good" in 54 per cent, "satisfactory" in 18 per cent, "poor" in 25 per cent and unknown in 3 per cent

Osgood, Campell and Orr, at the request of the American Orthopedic Society, reported in 1928 on 201 patients over 60 years of age with fracture of the femoral neck After one year, 30 per cent of them showed bony union Primary mortality was 28 per cent In 1930 the same group reported 262 cases of femoral neck fracture patients under 60 years of age In that group 52 per cent showed bony union and primary mortality was 9 per cent All of these cases were treated according to the method of Whitman

Whitman himself has not reported the end-results in his own cases

Hubner published statistics of 132 cases treated at the Charité in Berlin between 1912 and 1921 Only 6 per cent of those went on to healing, 18 per cent showed functional and anatomic results which were considered to be satisfactory, and the results were considered to be poor in 75 per cent

55. OPERATIVE TREATMENT OF ADDUCTION OR VARUS FRACTURES OF THE FEMORAL NECK

History Before the introduction of Whitman's conservative method, fractures of the femoral neck only rarely went on to bony union in good position Therefore, attempts to treat these fractures by open operation were made again and again Langenbeck in 1858 was the first to try putting screws across the fracture using an extra-articular approach Konig followed with a similar operation in 1875, and in 1876 Heine used an ivory peg In 1897, Nicolaysen in Oslo presented a series of cases in which extra-articular nailing



1651, April 27, 1928



1652, April 28, 1928



1653, July 16, 1928



1654, October 3, 1928

FIG 1651 —Medial femoral neck fracture with severe displacement sustained by a 34 year old unskilled worker who slipped on wet ground and fell Severe lateral displacement and antecurvature of fragments The femoral head appears round because the fracture surface looks anteriorly

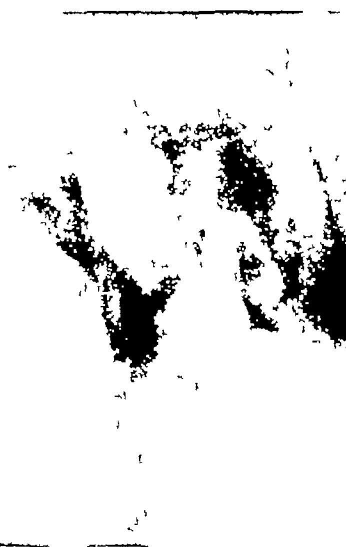
FIG 1652 —Check roentgenogram re figure 1651, taken with the patient in plaster after an unsuccessful attempt at reduction Owing to excessive longitudinal traction there is now severe valgus instead of the former varus position The fragments gap on the medial side The round shape of the head shows that the fracture surface still looks anteriorly The angle between the fragments is open posteriorly and laterally They are in contact only along one edge, not across the entire fracture surfaces

FIG 1653 —Check roentgenogram re figure 1651, three months later Valgus position and gaping have become worse Apparent increase in density of femoral head

FIG 1654 —Check roentgenogram re figure 1651, after five months Extensive absorption of distal end of the central fragment In such cases a femoral head prosthesis is indicated



1655, November 15, 1928



1656, January 22, 1929



1657, October 19, 1934



1658, December 21, 1937

; 1655—Check roentgenogram re figure 1651, six and a half months after the injury and o weeks after removal of the plaster cast Good alignment of fragments The femoral head distinctly smaller and more sclerotic than normal The calcium content of the surrounding bones is diminished Suitable time for an endoprosthesis

; 1656—Check roentgenogram re figure 1651, after nine months Only a calotte of the head has remained Trochanter displaced cranially

; 1657—Check roentgenogram re figure 1651, after six years A small "rest" of the head ; remained This is a rare end-result The caudal edge of the femoral neck is propped ainst the acetabular roof The neck is sclerosed, as it bears the weight of the body in lking Decreased density of trochanter Pain on walking Patient cannot walk long distances Hip flexion 180⁰—90⁰ Rotation only slightly limited

; 1658—Check roentgenogram re figure 1651, after ten years The femoral neck has become ; concave, and a marginal exostosis of the acetabular roof has become the convex, part of iew joint Hip flexion 180⁰—90⁰ Rotation almost free Gait slightly limping *without* a stick She works all day as a packer



1659, September 23, 1929



1660, September 27, 1929



1661, October 10, 1929



1662, May 2, 1930

Fig 1659—Fresh, medial, intracapsular, adduction or varus fracture of the femoral neck caused by a fall in a 53 year old female A long spur of bone projects from the inferior end of the head fragment *The fracture line does not run transversely to the axis of the femoral* neck but parallel with the long axis of the body (Pauwels III) Equal density of femoral head, femur and pelvis

Fig 1660—Check roentgenogram re figure 1659, after reduction and application of a plaster cast Good alignment of fragments

Fig 1661—Check roentgenogram re figure 1659, two weeks later Cranial displacement of neck and femur because too short a plaster spica had been applied reaching up only to the rib-arch (figs 2081, 2082)

Fig 1662—Check roentgenogram re figure 1659, seven months after injury Relatively increased density of head fragment This is evidence that the head fragment has inadequate blood circulation and therefore is dead



1663, June 6, 1931



1664, June 6, 1931



1665, October 19, 1934



1666, December 21, 1937

FIGS 1663, 1664—Check roentgenograms re figure 1659, with limb in external and internal rotation 21 months after injury The gap of non-union is not visible in external rotation but becomes visible in internal rotation Uniformly increased density of the head still seen Partial absorption of both bone ends Normal width of joint space Calcium content increased in peripheral fragment Beginning ossification of capsule and ligaments about cranial and caudal parts of the joint The lesser trochanter is propped against the neck portion of the head fragment Walking painful and limping

FIG 1665—Check roentgenogram re figure 1659, with limb in external rotation, after five years The neck portion of the head fragment has disappeared Only a calotte remains of the head Big cyst in its caudal part Neck and lesser trochanter are propped against what remains of the head Ossification of capsule and calcium content of shaft fragment and pelvis have increased Hip stiff in extension Walks with a stick for four hours at a time Pain in the knee

FIG 1666—Check roentgenogram re figure 1659, after 5½ years Head still smaller, its distal part is sclerotic Bony union between neck and what remains of the head Almost normal density of head, trochanter and pelvis Diminished density of the now functionless tip of trochanter Ossification of capsule increased Joint-space blurred Hip stiff in extension and mid-rotation Shortening 3 cm Walks almost without a limp with a sole raised by 3 cm Hip painless She can work all day as an ironer



1667, January 29, 1931



1668, June 30, 1931



1669, October 10, 1932



1670, May 24, 1933

FIG 1667 —Medial adduction or varus fracture of the femoral neck sustained by a 24 year old dancer who slipped on a wet floor Reduction two days later and large plaster spica for four months Stayed in bed throughout this time

FIG 1668 —Check roentgenogram re figure 1667, five months later Bony union in good alignment The head is strikingly dense, whereas the surrounding bones, especially the femoral neck, are atrophic Walks well

FIG 1669 —Check roentgenogram re figure 1667, 21 months after injury Walked without complaints for one year and could dance Pain for the past half-year Therefore massage and passive motion were given Condition thereupon deteriorated rapidly Hip flexion 180°—150°, rotation almost zero, abduction a few degrees Large depression of the head at the site of weight-bearing A big piece of the medial part of the head remains unchanged The upper part of the neck is sclerosed

FIG 1670 —Check roentgenogram re figure 1667, 27 months after injury Small sclerosed sequestrum below the acetabular roof Normal calcium content of the upper part of the neck regained, a sign of normal circulation and nutrition The lower portion of the big sequestrum seen in figure 1669 has been resorbed and partly replaced by new bone Prof A W Meyer, of Berlin, and Prof Haß, of Vienna, gave permission to publish figures 1667, 1668 and 1670—1673 respectively



1671 a, October 12, 1933



1671 b, September 7, 1934



1672, July 3, 1935



1673, January 5, 1938

FIG 1671 a—Check roentgenogram re figure 1667, 33 months after injury The sequestrum has become smaller The cavity underneath is disappearing Small marginal exostosis from the acetabular roof

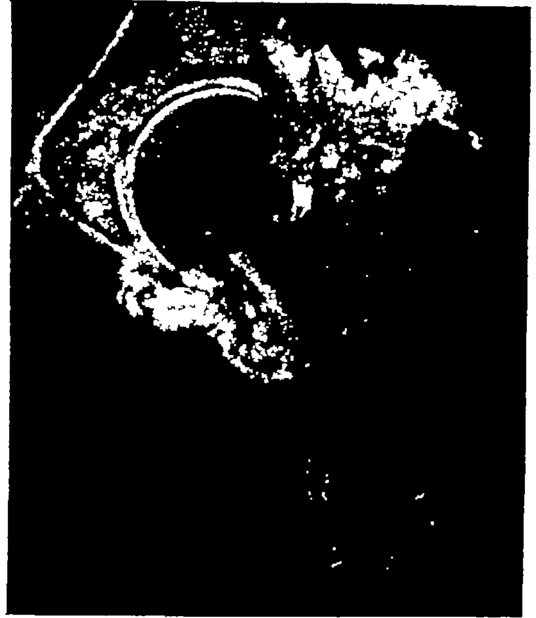
FIG 1671 b—Check roentgenogram re figure 1667, 45 months after injury The sequestrum has further diminished in size Normal density and almost normal structure of the head Patient walks well

FIG 1672—Check roentgenogram re figure 1667, four and a half years after injury The sequestrum has been resorbed A small cyst is all that is left of its bed

FIG 1673—Check roentgenogram re figure 1667, seven years after injury The former bed of the sequestrum has become the concave part of a joint, the marginal exostosis of the acetabular roof has become the convex part of that joint Changes have occured similar to those in figure 1658 Normal structure of bone at the site of the former sequestrum Normal calcium content of the neck and what remains of the head New alignment of the trabeculae in the femoral neck Patient walks well without limp and without pain Mobility of hip in all directions 66 per cent of normal



1674



1675



1676



1677

Fig 1674—Vertical section through a ten day old impacted subcapital fracture of the femoral neck Shortening of the limb through cranial displacement of the neck, coxa vara The caudo-medial cortex of the neck (calcar femorale) has been impacted into the head In spite of the impaction, this type of fracture usually goes on to non-union unless accurate reduction and uninterrupted immobilization are carried out

Fig 1675—Longitudinal section through a subcapital fracture of the femoral neck A fold of the upper part of the capsule has been caught between the fragments

Fig 1676—Longitudinal section through a several months old fracture of the femoral neck A part of the upper capsule has been twisted round the acetabular lip, a part of the lower capsule has been interposed between the fragments Head and neck have to a large extent disappeared Partial necrosis of the head

Fig 1677—Longitudinal section through a five year old subcapital fracture of the femoral neck The dead parts of the bone are white, they surround a well-nourished piece of bone near the entrance of the artery of the ligamentum teres

had been done Intra-articular suturing of the fragments was often attempted but, because of its technical difficulties, quickly abandoned The operative method of treatment of these fractures was particularly developed in France by Delbet and his followers He used an extra-articular method, using at first screws of metal and wood and then later autogenous peg grafts from the fibula Results improved only after the development of special operating tables and roentgen apparatus made possible a more accurate application of the operative method Robineau and Contremoulin constructed a very complicated apparatus for determination of the direction of fixation devices and achieved good results Lambotte exposed the fragments and then inserted two or three metal screws

While there was great interest in the operative treatment of fractures of the femoral neck among the surgeons in France and America, nearly no attention was given it in the German-speaking countries Kocher in 1896 developed an operation for removal of the femoral head first carried out by Howe in 1877 The results were, however, bad and the patients so operated on were still on crutches many years later Hotz in 1923 suggested the use of femoropelvic screws, and this method has since been reported on by Richard In his book on the operative treatment of fractures, Konig mentioned just a single case of fracture of the neck of the femur, while Demel mentioned none at all On the whole, German-language authors directed their attentions to the conservative methods of Whitman, Lorenz and Lofberg Lexer in particular worked with operative treatment, but only for old cases

Intra-articular Nailing Operations using autogenous or heterogenous bone pegs are technically very difficult, while ordinary screws or nails do not get sufficient grip in the spongiosa of the femoral head and neck But the whole problem was changed in 1925 when Smith-Petersen, of Boston, devised the three-flanged nail which bears his name The nail is made of stainless steel and has a thin central column from which three thin flanges radiate at 120^{0} intervals These flanges extend out 4—6 mm from the central steel column, and the whole nail is so small in volume that it does not destroy much of the spongy medullary portion of the bone despite which it becomes so firmly fixed that soon after introduction it can be removed only with considerable difficulty After such a nail has been driven in, the bone fragments can no longer rotate about their long axes as they can when an ordinary nail, a screw or a round peg has been used

The development of stainless nonmagnetic steel and of shock-proof high-voltage X-ray apparatus meant still further advances for the operative treatment of these fractures Ordinary steel buried in the body frequently stimulated marked foreign-body reaction, so the nonmagnetic stainless steel avoiding this was an important advance And it was only with the development of the shock-proof high-tension X-ray tube that one was enabled to get adequate lateral roentgenograms of the hip during operation Smith-Petersen himself inserted his nail after first having opened the hip joint widely, exposing the fragments This meant for elderly and weak patients a procedure of arresting magnitude and one attended by considerable danger of infection

The fact is that most authors reporting on the use of this operation reported deaths from sepsis And in addition, vessels contributing to the blood-supply of the femoral head are disturbed with this method

Extra-articular Nailing In 1932, Jerusalem in Vienna and Sven Johansson in Gothenburg simultaneously and independently suggested that, after reduction had been accomplished, a guide wire be inserted through the greater trochanter and a cannulated three-flanged nail then passed over it Exposure of the hip joint thus became unnecessary and the operation for hip nailing thus became a relatively minor procedure, the danger of infection being, of course, markedly reduced.

The main problem now is to determine exactly the direction in which the guide wire should be inserted and then quickly to ascertain that it has been eventually inserted in just that direction Sven Johansson devised a special guidance apparatus similar to those used by Delbet, Girode and Ostrowski, and then later a great many more were devised, e g , those of Hey Groves, Valls and Juillard Felsenreich suggested the regular use of two X-ray tubes to make possible rapid X-ray examination in the two projections Views in both projections are absolutely essential, and many of the earlier failures in extra-articular nailing were due to the fact that roentgenograms were made in only the A-P projection so that the screws, pegs or nails might actually be directed much too far ventrally or dorsally and still appear in the single-plane roentgenograms to be in perfect position Felsenreich also improved the three-flanged nail by broadening the flanges

Extra-articular nailing with the three-flanged nail is at the present time the best treatment for adduction or varus fractures of the femoral neck The patients so treated generally are up without any immobilizing bandage two weeks after operation, usually leave the hospital three weeks after operation and walk without a cane two to three months after operation

Lately this operation has come to be regarded by some surgeons as a more or less trivial procedure In reality, however, it requires much equipment, careful and thorough preparation and meticulously exact technique, since results are good only when *accurately reduced fragments are firmly held by an accurately positioned nail* **The surgeon who nails a fracture of the femoral neck without sufficient preparation assumes a grave responsibility, since he must know that a patient with a badly nailed femoral neck fracture is far worse off than a patient with a fibrous union of such a fracture.** Bad results reported from many quarters caused much of the early enthusiasm for this operation to abate But when one inquires into the causes of these failures one finds that gross technical errors were committed It should be remembered, though, that avascular necrosis with collapse of the femoral head may supervene after even a year or more of well-being (figs 1772—1777, 1779—1799, 1732—1737)

Preparation for Extra-Articular Nailing of a Femoral Neck Fracture

For *reduction* and *internal fixation* of a fracture of the femoral neck one needs·

1. Local anesthesia (Vol I/pp 118—120, fig 152)
2. A-P roentgenograms with the limb in external and internal rotation and a single lateral roentgenogram (figs 1594—1596, 1716, 1717)
3. Screw traction apparatus for the limb (Vol I/figs 103—105, fig 1700) or some other suitable traction apparatus,
4. A wooden pelvic support 40 cm broad with double bottom so it can receive the cassette for A-P roentgenograms
5. A knee prop (fig 1700 a)
6. Supports for the back and head (fig 1700)
7. Two gaiters (figs 1701, 1702)
8. Two stitched pads, 2 5×36×36 cm , for the wooden pelvic support
9. A warm jacket
10. A warm "sleeve" for the sound limb
11. A warm blanket for the back
12. A light-cradle with which to warm the bed
13. Two high-voltage X-ray tubes
14. A Jeschke wire grid (figs 1696, 1702, 1718, 1720)
15. An injection needle or a metal pin 8 to 10 cm long and about 1 5 mm thick for insertion as an X-ray-opaque indentifier of the femoral head (figs 1678, 1711, 1715, 1720—1723)
16. An injection needle or a metal pin 12 to 15 centimeters long and about 1 5 mm thick for X-ray-opaque indentification of the lateral margin of the femur (fig 1678)
17. A "water-bubble" level for the cassette (figs 1694, 1695) or Scherbichler's metal cassette holder with incorporated level
18. Rapid developer (see page 1253)
19. A transparent plastic rule
20. A transparent plastic protractor (Vol I/fig 57)
21. A protractor to determine the angulation of the femoral neck axis in the lateral view (figs 1711, 1712) and a rubber band for indication of location of the guide wire (fig 1710)
22. The usual instruments for open operations (e g , scalpels, forceps, scissors, clamps, retractors, needles, needle-holders, etc)
23. A large and deep self-retaining retractor
24. A small gouge, 6 mm broad (fig 1688)
25. A sharp chisel, 6 to 8 mm broad (fig 1689)
26. A hammer (fig 1686)
27. Some sufficiently firm guide wires, 2 × 2 mm thick and 22 cm long (figs 1768, 1681, 1691)
28. Desoutter's compressed-air drill with wire guides (fig 1696) and a tank of compressed air, or
29. An electric drill with wire guides (fig 1699), or
30. An ordinary hand drill-stock (Vol I/fig 132)
31. An adjustable "oil-bubble" level for attachment to one of the above drills (fig 1696)
32. A handle for manual insertion of a guide wire (fig 1692)

33 A wire indicator, 48 cm long and 4 mm thick, with a set-screw for connecting the guide wire in the femoral neck to the "oil-bubble" level and the drilling appliance (fig 1679)
34 Sterile pillow-slips for covering the cassettes used for the lateral roentgenograms during operation
35 A cannulated cortex trephine of 8 mm diameter (fig 1678)
36 Two sets of the Smith-Petersen & Johansson cannulated three-flanged nails modified so that the central canal is threaded for a few millimeters at the outer end (figs 1680—1682)
37 A metal measure tape (fig 1693)
38 A nail driver perforated so as to pass over the guide wire (fig 1684)
39 Strong pliers for pulling out the guide wire (fig 1690)
40 Smith-Petersen's impactor (fig 1683)
41 Smith-Petersen's nail extractor (fig 1685)
42 A small steel attachment with male threading on one end for introduction into the end of the nail and with an "eye" for receiving the hook of the Pohl and Kuntscher extractor device (figs 1678, 1679)
43 Strong, hooked extractor of Pohl and Kuntscher to be used with the attachment listed as number 42 (fig 1679)
44 Slotted hammer of Pohl and Kuntscher for use with the extractor listed as number 43 above (fig 1679)
45 Stainless steel plates 8 cm. long and longer and with one end adapted for attachment to a three flanged nail (fig 1678)
46 Two bending irons (fig 1679)
47 Spring washer of 10 mm external diameter and of size to fit the screw as listed in number 48 below (fig 1678)
48 Screw for fixing the plate (number 45 above) to the three-flanged nail (fig 1678)
49 Forceps for holding and inserting that short metal-screw (fig 1678)
50 Screw driver for that screw (fig 1678)
51 Socket-wrench for setting home that metal-screw (fig 1678)
52 A three-millimeter drill for boring the holes in femoral cortex to receive the bone-screws (fig. 1678)
53 Bone-screws, 3 5 mm thick and 35—45 mm long (fig 1678)
54 Screw driver and screw holder for inserting the bone-screws (fig 1678).
55. Small sterile instrument table holding the Jeschke wire grid (fig 1696), some pointed steel wires 8 to 15 cm long, and two forceps
56 Small sterile instrument table with a local anesthesia set-up (see Vol I/fig. 152)
57 One surgical assistant
58 Anesthetist for observing the patient and giving anesthesia if necessary
59 Instrument nurse, and
60 Two X-ray technicians, one to take roentgenograms and the other to do the rapid developing of them

Testing the Material for Resistance to Rust or Corrosion.

All nails, plates, screws and wires to be buried in the body and to remain there either temporarily or permanently must be noncorrosive, i e, stainless and acid-resisting Austenitic chromium-nickel steels have this quality Their composition is described on page 1245 Martensite steels with little or no nickel content oxidize and decompose in the body, as shown in figs 1802 through 1806 The bone is destroyed and the surrounding tissue is discolored brown and black Sometimes a discharging sinus develops and secondary infection occurs Pain is usually noted, especially at night

To protect the patients from damage caused by rusty material, all nails, screws, plates and wires to be left in the body for any considerable time or permanently should be tested with a magnet, since magnetic steels are often incorrectly supplied All magnetic material should be rejected at once (figs 1700 b, c)

Jeschke's Wire Grid

It consists of twice nine pieces of strong nickel-plated brass wire so arranged as to intersect one another at one-cm intervals and therefore to form 64 one-cm squares outlined by the X-ray-opaque wire Its presence in the roentgenogram facilitates location of the points where the guide needles or pins should be inserted

Metal Guide Needles or Pins

These are 8—10 and 12—15 cm long and 1 5 mm thick Each has a "head" 2 mm thick on one end and is pointed on the other, this form facilitating differentiation of the two ends on the roentgenograms (fig 1678)

Desoutter's Compressed-Air Drill

Since 1947 we have generally used Desoutter's drill (fig 1696), as we often had trouble with the motors of electric drills used in such operations Before operation, of course, one should check the compressed air tank to be sure that it is full

"Oil-Bubble" Level

The coronal axis of the femoral neck is measured on the lateral roentgenogram and then the guide wire should be drilled in accordingly We formerly used Moltgen's protractor and a water-level, which of course had to be held by an assistant Now we use an air-bubble in an oil column as a level, and this is adjustably attached to the drill and can, before the wire is drilled in, be set at exactly the angle determined from the roentgenogram (figs 1696, 1715)

Thickness, Length and Material of the Guide Wire

At first I used guide wires which were 1 5 mm thick However, they used to bend when they came up against hard portions of bone and then were caught by the nail as it was inserted and were driven in deeply and either

bent (fig 1744) or broken (figs 1739—1742) In the literature there are also many cases reported in which the wires had been driven on into the pelvis and had injured the bowel or bladder In order to avoid these difficulties I now use only 2 2 mm thick, highly-polished, nickel- or chromium-plated piano wire, which is comparatively hard but not too brittle Each wire is 22 cm long (fig 1681) With this length and with the wire guide apparatus

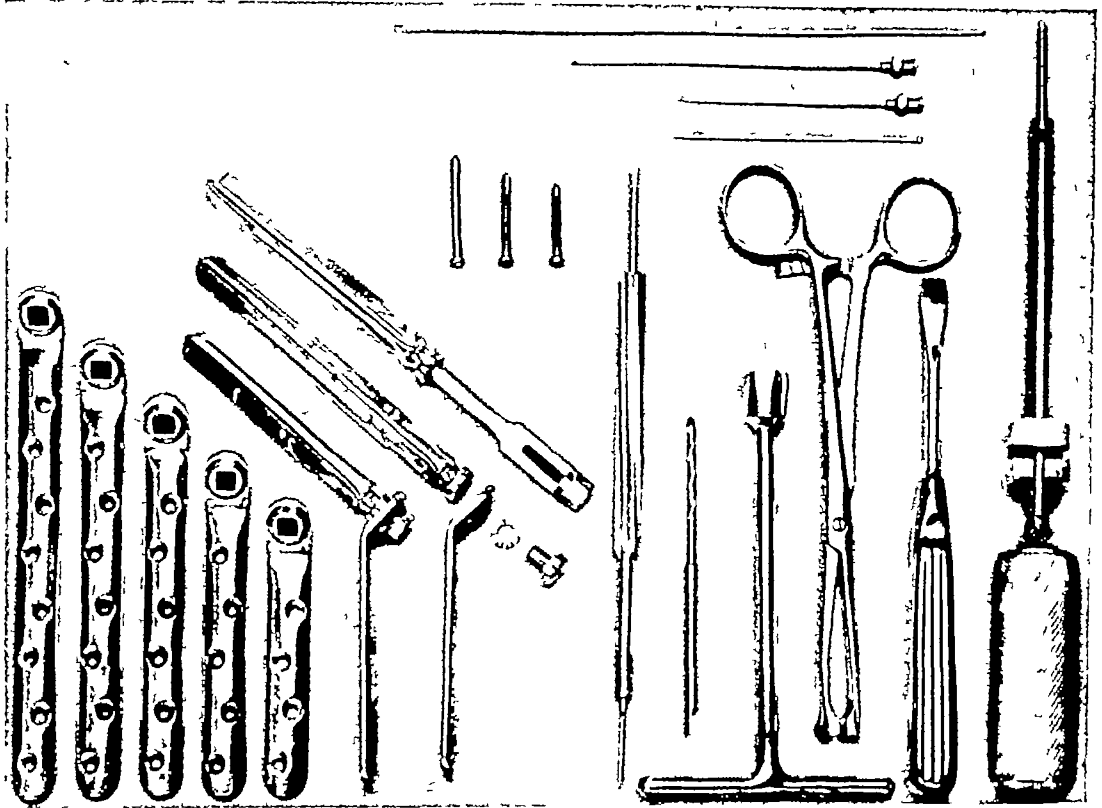


Fig 1678—On the extreme left, five stainless steel plates, 8 to 16 cm long Next to them, a three-flanged pin with plate, washer and screw once assembled, once separate Above the latter, a three-flanged nail with the pull-out device screwed on Above this, three bone screws 35 to 45 mm long In the middle of the picture, a cannulated drill with a guide wire On its right, a drill for the bone screws Next right, a socket wrench with a bore of 10 5 mm for the thick screw which serves to fix the plate to the three-flanged nail and which has a threaded portion 10 mm long and 1/4-inch in diameter Then next right, forceps to hold this screw And next, a simple screw-driver On the extreme right, a screw-holding screw-driver with screw At the top, placed horizontally, a 25 cm long wire with hooked end for measuring the depth of the drilled holes for the bone screws Below that are injection needles 15 and 8 cm long, and a metal guide pin 9 cm long

that we use (figs 1698, 1699, 1715), the wires are prevented from penetrating the pelvis and entering the abdominal cavity The guide wires need not, of course, be noncorrosive and nonmagnetic, since they are not left in the body

Cannulated Trephine

If the nail is driven in over the guide wire without notches' having been cut in the femoral cortex for the flanges, they may break away a piece of the

cortical bone To avoid this, we now first thread a cannulated trephine over the guide wire and bore a hole in the cortex to receive the nail

Material and Form of the Three-Flanged Nail

Material and Manufacture of the Nail We are now using three-flanged nails made of SAS 4-steel, which has essentially the same composition as Krupp's 4 A-steel and is stainless, acid-resistant and nonmagnetic Its analysis shows 18 parts chromium and 10 parts nickel alloyed with silicon, manganese, molybdenum, tantalum and niobium In order that one can be sure that all material to be buried in the body is nonmagnetic, every single piece of it should be tested with a magnet If it is to be used, then, it must not be

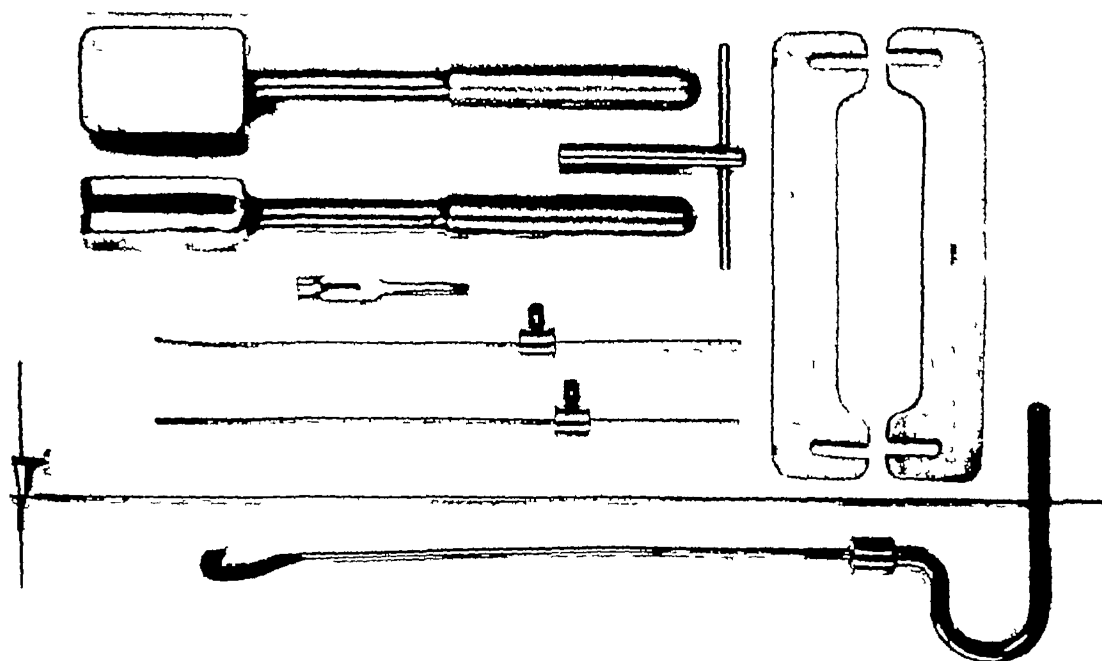


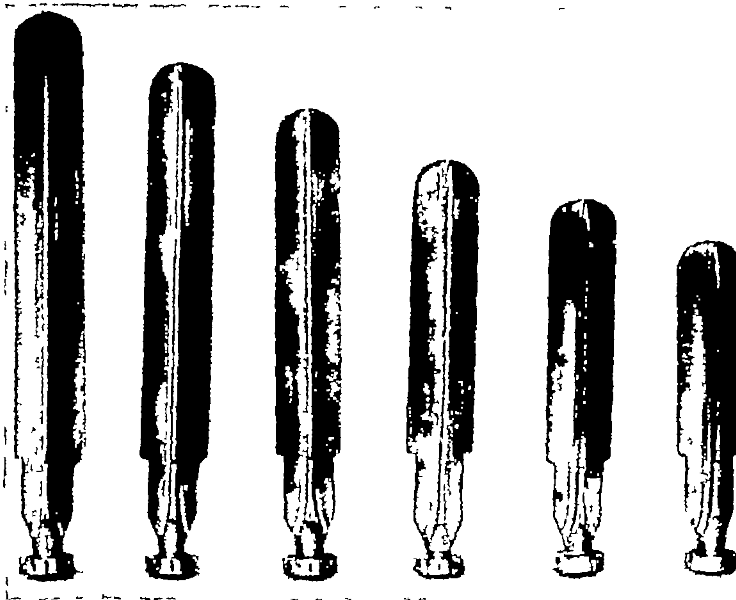
FIG 1679—Top left, the hammer with slotted head (Kuntscher and Pohl) seen from two sides Top center, the socket wrench for the strong set-screws Upper right, two bending-irons for plates Left center, the pull-out device to be screwed into the head of the three-flanged nail when it is to be removed Below it, a slightly bent guide wire with a hook and strong screw for extracting broken three-flanged nails Below it, a threaded guide wire with a strong set-screw to extract broken three-flanged nails Further down, the 48-cm-long metal indicator to be put on and fixed by a set-screw to the guide pin stabbed into the femoral head It indicates the direction for the guide wire Below it, the strong hook which catches the pull-out device to extract the three-flanged nail

attracted by the magnet — as are those products made, for example, from martensite steels Martensite steels are chrome steels, and the tendency toward rusting of steel is influenced primarily by its chromium content These high-crome steels oxidize in the body tissues and corrode Some austenitic steels react slightly to the presence of a magnet when they are freely suspended from their centers of gravity, though they are really resistant to corrosion and rust

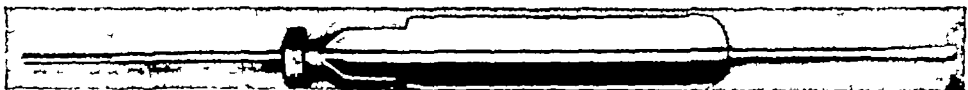
The first nails I used, which had been obtained from several different countries, often became rusty With some of them it was possible to recognize

roentgen evidence of corrosion after only a few weeks (figs 1802—1806) When I had several nails analyzed it was found that they were of steels of the most varied sorts and that the nickel content was too low

Nails should also be sufficiently sturdy so that they do not bend or break. Felsenreich found in 400 cases reported in the literature that the nail had broken in 13 cases, while in my first 217 cases I had two in which the nail broke In both of these the fault lay not in the use of inadequately strong nails but rather in the fact that the nails had corroded



1680



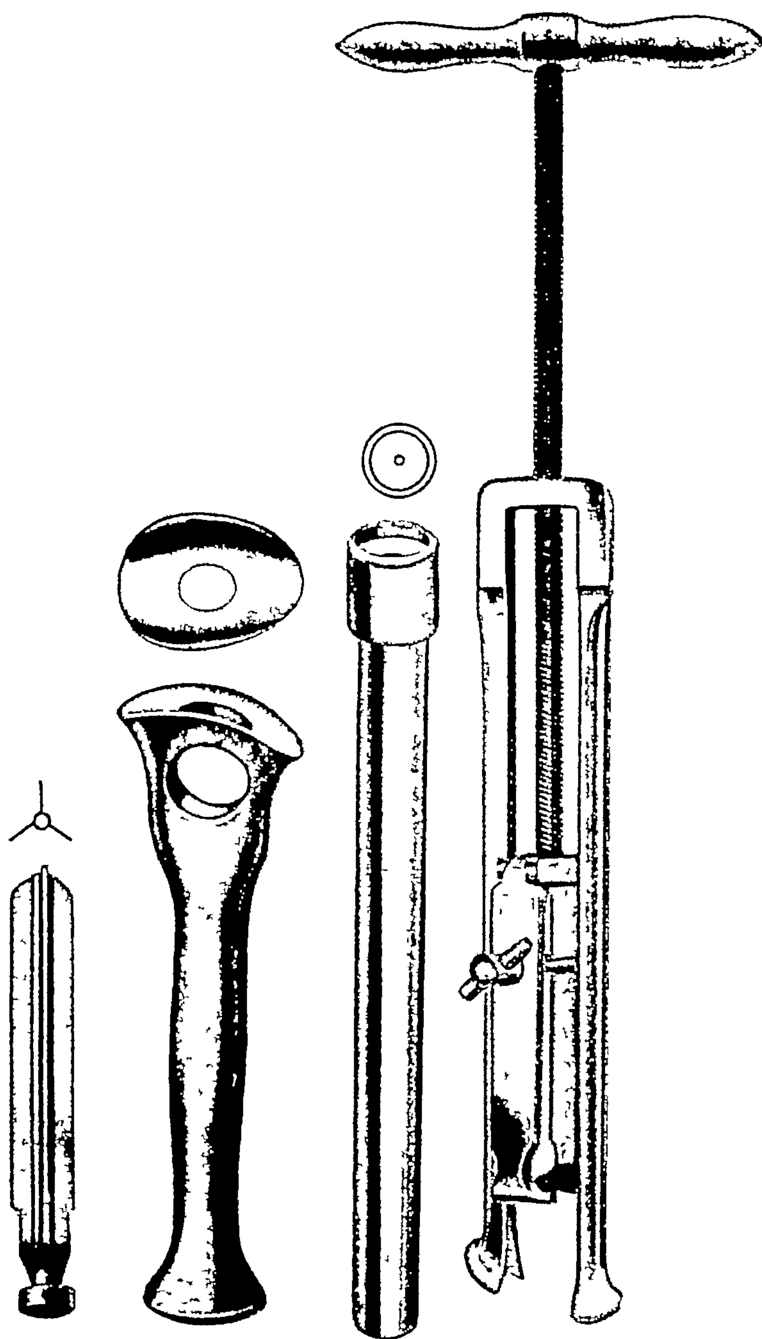
1681

FIG 1680—Six different lengths, 7 cm to 12 cm, of the three-flanged nails (Smith-Petersen and Sven Johansson) Each nail is milled out of a single piece of stainless, nonmagnetic steel and is cannulated throughout its length (For hip arthrodesis, nails 13 to 17 cm long are used) The ends of the flanges are rounded off to prevent them from projecting into the joint Towards the head the flanges taper to allow for the impaction punch and to avoid extrusion of the nail from the bone At present we use only nails with a thread cut into the heads to allow fixation of a plate if necessary or to receive the pull-out device (fig 1678) for removal of the nail

FIG 1681—Three-flanged nail with 2 2 mm-thick guide wire On the right the pointed end, on the left the squared end to fit into the handle (fig 1692)

Nails the heads of which are riveted or welded on are particularly prone to rust If copper alloys are used for welding, as was true in the case shown in figures 1798 and 1799, severe bone destruction results

Shape and Construction of the Three-Flanged Nail The first nails I used were ones I received from Smith-Petersen when I visited him in Boston in 1930



1682—1685

FIG 1682—Three-flanged nail (Smith-Petersen) modified by cannulation throughout its length (Sven Johansson) A thread is cut into the head of the nail

FIG 1683—Modified impactor (Smith-Petersen) with broadened headpiece It is placed on the lateral surface of the femur over the head of the pin, and by hammering upon it one can when necessary cause the neck to be impacted into the head

FIG 1684—Modified driver (Smith-Petersen) with central bore (Sven Johansson) and added ring for holding loosely the head of the nail

FIG 1685—Modified Smith-Petersen instrument for withdrawing the nail The shanks are of unequal lengths and their lower ends are oblique and broadened The jaws of the extractor part have reinforced and rounded grips The screw thread is stronger, its pitch greater

He showed me at that time his method of operation and his cases These pins had sharp-cornered flanges and the heads were welded on On post-mortem examination of one patient in whom a femoral neck fracture had been nailed I found that the sharp corner of one flange had penetrated several millimeters through the articular cortex of the femoral head and extended into the joint space although it appeared in the roentgenogram to be in good position Therefore I had the ends of the flanges rounded off (figs 1680—1682) In another case I found severe corrosion at the site of welding when the nail was removed some months after operation, and the tissue about it was brown and black Moreover, the head of the nail sometimes broke off Therefore I had the head riveted on, but I later discovered that there was also a tendency to rust at the site of the rivet So now I have the nails milled each from a single piece of metal In this way we avoid those rough spots on the surfaces of nails made otherwise and which are the sites of rusting, and also there is now no danger that the head of the nail will break off Following Felsenreich's suggestion, I have had the flanges made broader so that the nail gets a firmer grip in the bone In my nail, however, the broad parts of the flanges end 2.5 cm from the head so that the head itself is small If, therefore, a cannulated trephine is not used but linear defects are chiselled from the cortex to accommodate the flanges, the cortical surface against which an impactor of given diameter impinges is such that breaking of the cortex around the nail is avoided even in the relatively atrophic bones often found in these elderly patients An added advantage in having the flanges broader centrally than peripherally is that the "step" tends to prevent the nail from sliding out When in 1952 this "step" was omitted and a smoothly-curved transition was made from the broad to the narrow part of the flange, some of the nails slipped out So now again we use nails with the abrupt step Many surgeons use a steel nail or screw to prevent such slipping, but by this introduction of a second piece of metal there is introduced the danger that slight differences in the compositions of the two metals will cause electrolysis and, therefore, corrosion The central bore of our pin is 2 5 mm to accommodate our 2.2 mm guide wire (figs 1680—1682) Since 1950 I have had a screw-thread cut into the head of the nail so that a plate (fig 1678) or an extracting appliance (figs 1678, 1679) can be attached. The neck of the nail had to be increased in size from 7 5 mm to 8 5 mm. in order to give it sufficient strength At first we connected nail and plate with a hollow $^1/_4$ inch screw and a solid $^1/_8$th inch screw within it. Now we use simply a thick solid screw over a spring washer, the nail of course acting as the female member in the union

Checking the Nails and Guide Wires

All nails and wires to be included in the set-up for any operation must be thoroughly checked and tested beforehand All guide wires should be tested regarding their ability to pass smoothly through all nails, in order that eventual jamming may be avoided Nor must the wires be of too narrow gauge, lest bone splinters get caught between nail and wire as shown in fig 1746

The Driver

At present we use a driver 17 cm. long with a central cannulation 3 mm. wide. A metal socket of 1 mm. depth (fig. 1684) and with its external ring measuring 13 mm. receives and loosely holds the head of the nail during its insertion.

The Impactor

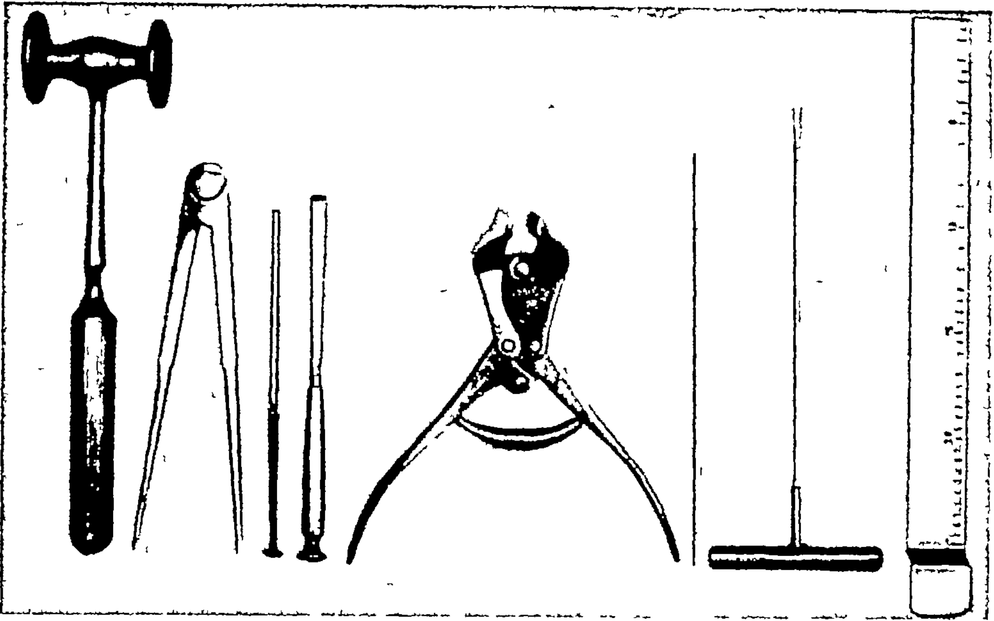
In nearly all the elderly patients and in those younger patients who have for some reason been confined to bed or otherwise inactive for a long time, the atrophic bone may be broken when an attempt is made to impact the fragments after introduction of the nail. To prevent that we have modified the impactor so that, while the central bore is 17 mm. — just big enough to receive the small head of the nail — the width of the area of surrounding impacting head is now 14 mm. This distributes the impacting force over a larger surface and so lowers its resultant pressure everywhere (fig. 1683). We now attempt to impact the fragments only in the rare case in which the roentgenograms show an actual diastasis between the fragments.

The Extractor

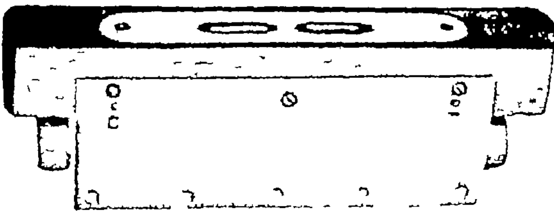
The old type of extractor we used gave us some trouble in that it tended to move from the axis of the nail, sometimes depressed the bone surrounding the head of the nail, was able to catch the head at times only with difficulty, and had too slight a pitch to its threading. The new instrument has the two shanks of slightly different lengths so that pull can be exerted more easily in the long axis of the nail, and the ends of the shanks are much broader and so tend to avoid depression of cortex. The clamps for holding the nail are longer and can be tightened about the head of the nail without interference from surrounding soft tissue. The jaws grasping the head are fitted to the newer heads, and the strengthened extracting screw itself has a steeper pitch thread so that the nail can be extracted quickly and easily (fig. 1685). However, we now use this instrument only if a wire should jam in the cannulated nail so that the newer extractor device (figs. 1678, 1679) cannot be used.

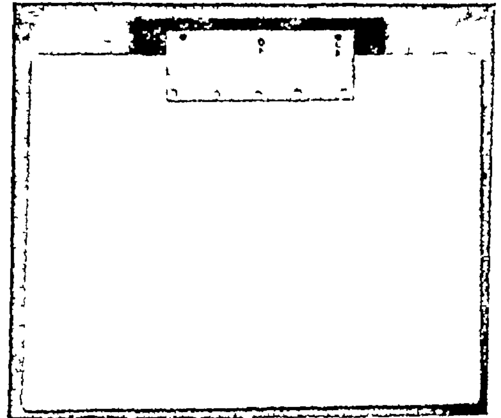
The Newer Extractor

Sometimes a nail must be removed during operation because it is of incorrect length, and sometimes one must be removed long after operation because the head has become necrotic and the nail has therefore penetrated the joint. At present we use the device shown in figures 1678 and 1679, which can be applied much more easily than the device shown in figure 1685. The intermediate piece 7.5 cm. long is screwed into the nail and set home with the socket wrench shown in figure 1679. The hook of the extractor itself as described below then fits into the 4×15 cm. long slot and the slotted hammer is slipped over the long shank of the extractor and used to pound out the nail. So no pressure is put on the cortex around the nail and, therefore, there is no danger of one's depressing it.



1686—1693





1694 1695

Fig 1686 – Strong hammer for driving in the nail Weight 0 5 Kg

Fig 1687 —Compasses for measuring the distance between greater trochanter and drill hole

Fig 1688 —Small gouge, of 6 mm diam, for cutting a notch for the guide wire

Fig 1689 – Small chisel for cutting a notch for the distal flange of the nail

Fig 1690 —Strong pliers for removing the guide wire

Fig 1691 – Guide wire 2 2 cm thick, 22 cm long

Fig 1692 —Handle for inserting the guide wire

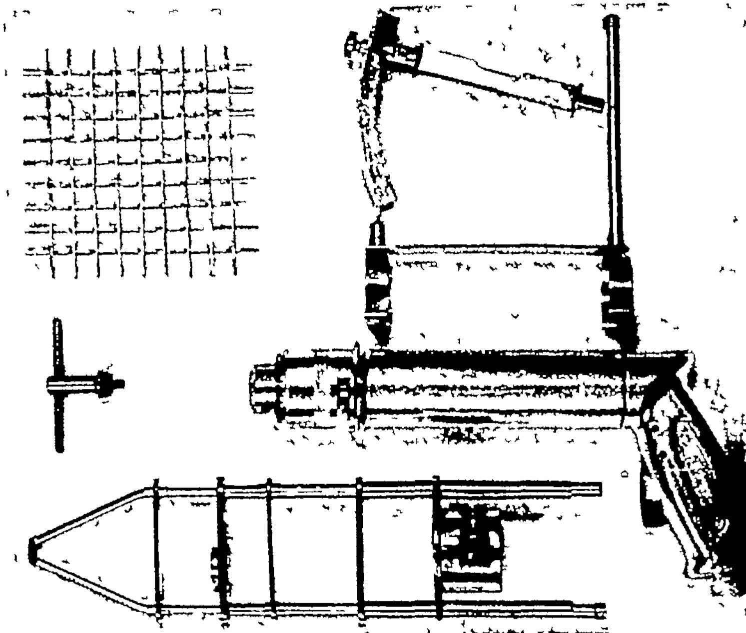
Fig 1693 —Metal ruler for measuring the nail

Fig 1694 – Water-level with metal plate and two steel springs to allow its attachment to the cassette

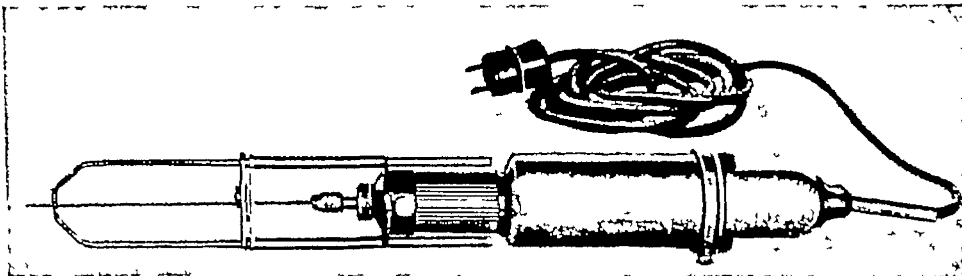
Fig 1695 Cassette containing 18 × 24 cm film and with the water-level in place

Shape and Strength of the Extractor

The hook (fig 1679) must be strong, since great strain is sometimes put on it in getting a nail out The first model of this type was too weak and often broke The hook at its angle should be at least 3 5 mm thick and the shank should be 5 mm thick



1696—1698



1699

FIG 1696—Top left Jeschke's wire grid Top right adjustable oil-level to be put on Desoutter's compressed air drill or on the electric "Aesculap" drill

FIG 1697—Center left key for fixing drills and wires Center right Desoutter's compressed air drill

FIG 1698—Bottom guide frame for the wire

FIG 1699—Electric "Aesculap" drill with guide frame for the wire and with cable

Frame for the Cassette in the Lateral View During Operation

For the lateral roentgenogram of the femoral neck (figs 1702, 1703) the cassette must be pressed in very firmly just above the crest of the ilium Lead gloves and a lead apron should always be worn for the protection of the indi-

vidual holding a cassette for such an exposure, but the sterile conditions of operation make that impossible So Scherbichler developed a 21 × 80 cm metal frame with attached water-bubble level and with two handles on one end and a receptacle for the cassette on the other When the cassette side is then covered with a sterile drape, someone not "scrubbed in" and who can, therefore, be properly protected against the X-rays can hold the cassette

Preparation and Testing of the X-Ray Apparatus

A good end-result can be achieved only by accurate reduction and uninterrupted immobilization The eventual adequacy of reduction can be checked only by good A—P and lateral roentgenograms Good roentgenograms in both projections are also needed to check positions of guide needles, the guide wire and finally the nail as well as to show the degree of eventual impaction So in the course of operation at least eight roentgenograms are necessary, viz, four in each projection Originally I used only one X-ray tube, the position of which then had to be changed several times during the operation This was time-consuming, it threatened to some extent the exactness of aseptic conditions in the operating room, and it resulted in slight variations from roentgenogram to roentgenogram because the tube was not always put in precisely the same spot for all exposures in each projection For these reasons I made the mistake in my first eight cases of trying to get along with too few roentgenograms and therefore had some failures. Since following Felsenreich's suggestion that one use two X-ray tubes, one for each projection, and leave them in place throughout the operation, we have had markedly improved results For a time I had only a single portable X-ray apparatus and so did the operation in our X-ray room in order that the fixed tube there might be used for the A—P projection Before one does this operation for the first time, or before one does it for the first time in any one hospital, one should check thoroughly the X-ray equipment and should train the whole involved personnel in its use for this procedure. A healthy "stand-in" for the patient should be put on the operating table and fixed there just as the patient is later to be, and then the X-ray tubes should be exactly positioned for the two projections (figs 1700—1702) If there is a difference in the kilovoltage of the two tubes, and if the one with the higher tension is shock-proof and sufficiently mobile, then that one should be placed between the legs near the sound-side knee and used for the lateral projection Whichever tube is used for the lateral projection must be so directed that its central ray is horizontal and crosses the femoral neck at an angle of 90° (fig 1703) The cassette should then be pressed firmly into the soft tissue just cephalad to the crest of the ilium and caudad to the ribs and so positioned that it is exactly vertical in its shorter dimension and exactly parallel to the femoral neck (therefore making an angle of 90° with the central ray) in its longer dimension (figs 1701—1703) If the cassette is not pressed in firmly enough, the medial part of the femoral head will not be projected onto the film The superior (ventral) margin of the cassette is adjusted to exactly horizontal by means of the built-in or attached level (figs 1694, 1695) The lower-kilovoltage tube, or

the one which is not shock-proof, is positioned for the A—P projection directly above (ventral to) the femoral neck and with its central ray exactly vertical The cassette for the A—P roentgenogram should then be slipped into the wooden receptacle beneath the pelvic support in such a way that all of the hip joint and trochanteric region will be projected onto the film The long axis of the cassette should parallel the long axis of the femoral shaft As soon, then, as the X-ray tubes are in correct position they should be fixed there so that all subsequent roentgenograms will be made in exactly the same projections With such an arrangement one can then get good roentgenograms in both projections and can get them quickly One should not start the operation before the adequacy of the set-up and the personnel has been demonstrated in the actual making of such roentgenograms

Before a hip-nailing operation I did in Spain in 1937 I needed four hours of work with the personnel before they were able to get good A—P and lateral roentgenograms on a "stand-in" Only then was the patient placed on the table The operation with all necessary roentgenograms was then done in forty minutes

Rapid X-Ray Film Developing

With ordinary developer it usually takes 8 to 10 minutes to get the developed and fixed films back into the operating room Since during operation at least four pairs of films are to be exposed, that means a "waiting-time" of forty minutes Often even more films are needed and so even more time is wasted Felsenreich has introduced a rapid developer the use of which allows one to have the roentgenograms in the operating room in three minutes

The rapid developer which we use is produced by Agfa and has the following composition

Solution I	500 cc	water
	50 Gm	pyrocatechin
	100 Gm	Na sulphite cryst
Solution II:	500 cc	water
	30 Gm	N hydrate
	50 Gm	K bromide

Following the advice of our photographer, Mr. Ester, we proceed as follows Both of these above solutions are prepared in boiling water Then just before it is to be used, the actual rapid developer is made by mixing together equal volumes of the two solutions The final solution can be used for only about one hour and then must be discarded Developing of properly-exposed X-ray film takes about 50—60 seconds Care must be taken to avoid soiling clothes or hands with the solution, since spots from the solution cannot be removed from fabrics and since the solution stains the skin The films should be handled with clamps, washed in clear water, and then fixed for about two more minutes Our fixative solution is

Solution·	1000 cc	water
	300 Gm	Na thiosulphate
	30 Gm	K metabisulphite

In order thereafter to make the roentgenograms durable they should be fixed in the solution for another ten minutes after they have been looked at by the surgeon and should then be thoroughly washed before being dried

It is possible that the roentgenograms can be brought into the light after only a half a minute in the fixing solution without their being completely ruined, but their quality is thereby markedly impaired The use of this fast developer shortens the operating time significantly, and there are now new

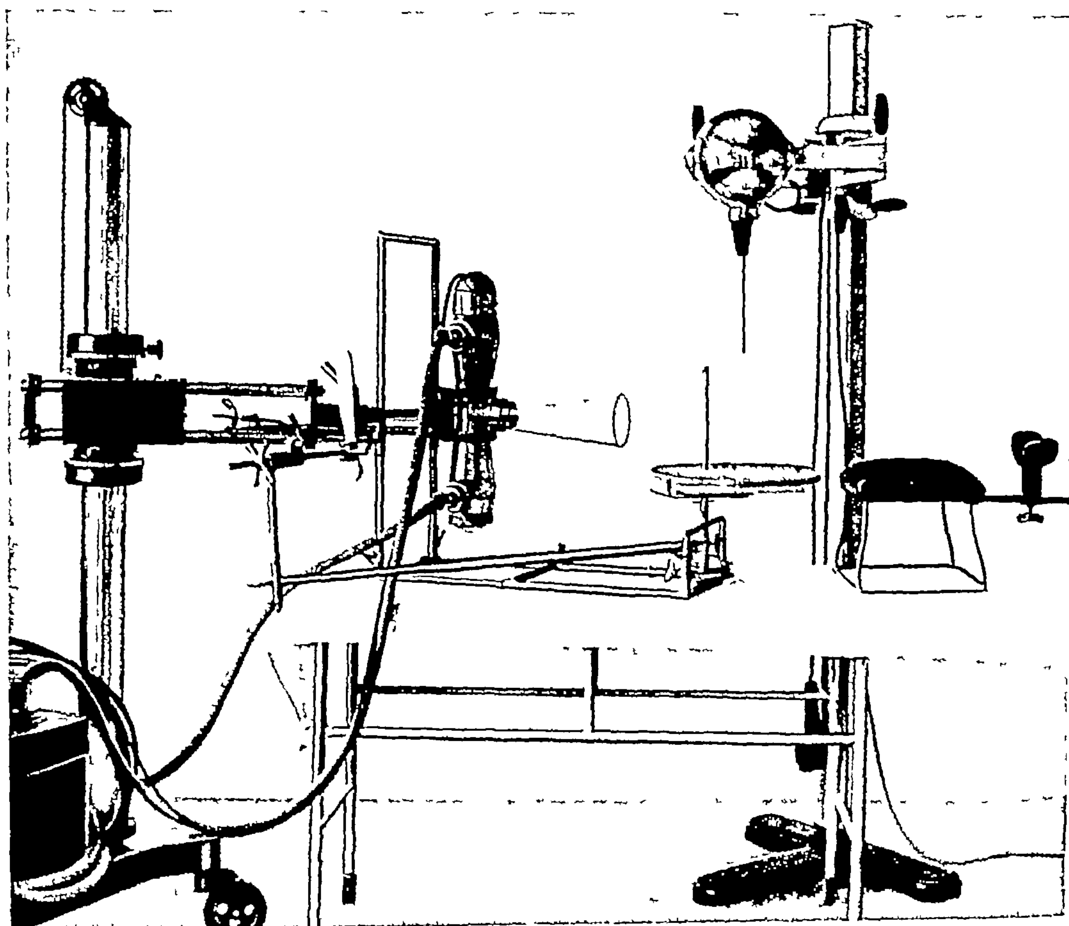


Fig 1700—Simple operation table with support for back and head, screw traction apparatus with 38 × 40 cm wooden pelvic rest for receiving the cassette, Siemens X-ray "ball" with central ray placed for the anteroposterior view, Muller standard X-ray tube placed for the lateral view

roentgenographic methods which promise to provide usable roentgenograms in as little as 30 seconds

Terms Indicating Position and Direction

Reference to direction or relative position in the human body must be exact and unmistakable The three main planes are the coronal (paralleling the coronal suture), the sagittal (paralleling the sagittal suture) and the transverse (at right angles to both the others) By using, then, those terms as well

as "cranial," "caudal," "ventral," "dorsal," "medial" and "lateral" we can usually avoid any misunderstanding While for the trunk and hip regions we

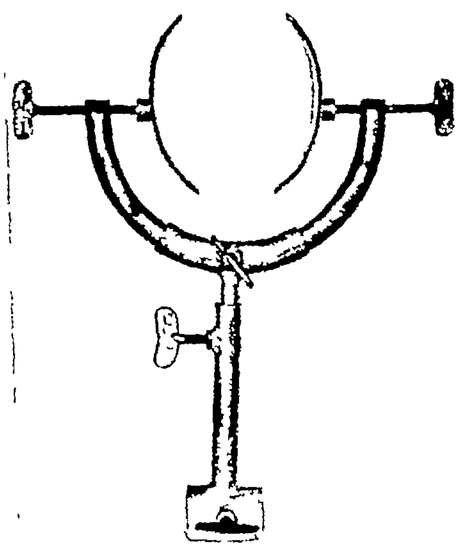
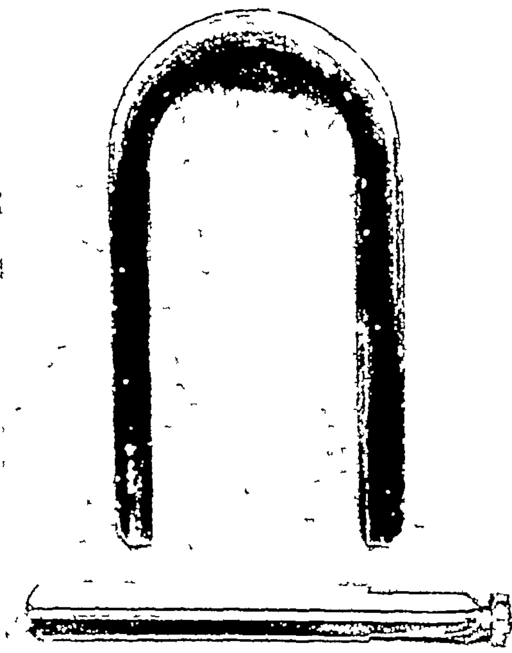
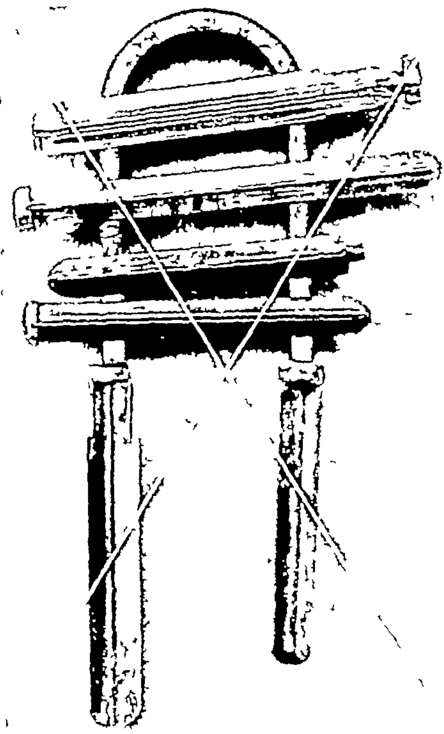


FIG 1700 a—Knee prop to be put on the long bar of the extension table or screw traction apparatus It can be lifted, lowered and tilted inward or outward If necessary, the knee can be held fast by the two pads



1700 b



1700 c

FIG 1700 b—Nonmagnetic, noncorrosive three-flanged nail of SAS 4 steel A magnet, 13×7 cm, fails to attract it All material to be buried in the body must be tested with a magnet prior to operation

FIG 1700 c—Six three-flanged nails of martensite steel with too little chromium content All six pins are attracted and held by a small magnet The top pin has not yet been used, so it is smooth and shiny The other five pins have been in the body for varied periods of time and are considerably damaged by rust

use these terms, for the limbs otherwise we generally use "proximal" and "distal," "central" and "peripheral," "anterior" and 'posterior" and "medial" and "lateral" — the latter two pairs being acceptable because the standard position of anatomical reference is so well known And of course there is no mistaking "palmar," "volar," "flexor," "extensor," "plantar" etc One should not, however, speak of "over" and "under," for example, unless he is prepared to be misunderstood Such terms are sadly inexact, since what is "above" with the patient standing up is not at all what is "above" with him lying on his back What is "above" with him lying prone is something else again, and with him on his side it is something still different "Ventral," however, remains "ventral"

When a surgeon asks his assistant to retract something "up" he may see that thing then retracted either cranially or toward the ceiling Quite obviously, one can be most certain of avoiding misunderstanding if one uses terms which refer to the body itself and which are entirely independent of the position of the body in space

EXTRA-ARTICULAR NAILING OF A FRACTURE OF THE FEMORAL NECK

If thorough examination has shown the patient to be in good general condition and not to be suffering from tabes or severe diabetes mellitus, operation can be done after proper preliminary treatment in skeletal traction (see page 1209)

The Fifteen-Second Breathing Test. An extraordinarily simple and reliable test of the cardiovascular and pulmonary systems simultaneously is this fifteen-second breathing test It might perhaps better be called the "fifteen-second no-breathing test," since it involves holding the breath with mouth closed and nose pinched off for fifteen seconds All the many other tests, some much more involved — e g , electrocardiograms, vital capacity, etc — have failed to yield for us as quick and reliable results as those from this simple test One should operate only if the patient is able to pass this test If he cannot, then he must be treated medically first and operated on only if and when he can finally pass it We have had many patients who at first were able to hold the breath only five seconds but who were able to hold it fifteen seconds or more after 4 to 6 weeks of medical treatment When this fifteen-second minimum is not reached, operation should not be done

Contraindications to Operation. If all goes well the operation should take about 40 to 50 minutes, though minor complications rather often occur and may lengthen it to 1½ to 2 hours One should not, therefore, operate on patients whose general condition is poor or who suffer from disease of the cardiovascular system, lungs, kidneys, bladder or prostate or on patients with uncontrolled diabetes or tabes Patients with well-controlled diabetes can, however, be operated on Patients with tabes should as a rule be excluded from operation since the result is usually poor and the blame is most often laid at

the surgeon's door by both patient and family Rauhs[1] has reported some cases of femoral neck fracture in tabetic patients whose fractures were internally fixed by nailing and who were thereafter kept in bed without any weight-bearing for 9 to 10 months In those cases there was bony union without necrosis of the femoral head If, however, weight-bearing is allowed in tabetic patients after nailing of femoral neck fracture, pseudarthrosis and fracture of the nail result (figs 1734, 1735) Tabetic patients with femoral neck fractures who are not operated on usually walk rather well despite non-union, since they of course feel no pain It may well be, then, that it is wiser to allow such patients to be up and about after three or four weeks rather than subject them to operation and then keep them in bed for the better part of a year As a rule we do not operate on patients who have been invalided for years or who have been bedridden for many months We have had some satisfying results, though, following nailing of pathologic fractures through areas of *metastatic tumor* In these cases a plate should be attached to the nail as in pertrochanteric fractures (fig. 1879) in order to provide a greater measure of stability

Time of Operation The operation is never urgent, so one should wait 2 or 3 days after admission of the patient until all examinations have been satisfactorily done The patient is kept in traction all this time and has usually recovered from whatever shock he might have had following injury In some cases in which the patient is admitted several days after injury the limb is found to be somewhat swollen In such cases one should wait until the swelling has completely disappeared with the limb elevated and in continuous traction In patients with disease of the heart, lungs or urinary tract it may be that under medical treatment they will recover sufficiently to warrant operation, though the period of needed treatment may last one or two months

Preparation for Operation

Half an hour before operation, while the patient is still in his room, he is given 0 02 Gm Pantopon, morphine or Heptadon by hypodermic injection and is then taken to the operating room in his bed and without interruption of the traction

Local Anesthesia of the Hip Joint. Local anesthesia is carried out as described on page 1209 In most patients the entire operation can be done under just local anesthesia, though sometimes general anesthesia is needed during trephining of the compact corticalis and during insertion of the nail and impacting We no longer use spinal anesthesia, since we have seen several cases in which its use has occasioned precipitous drop in blood pressure

Protection from Chill. In order to prevent chilling (see Vol I/p 135), limbs and trunk must be kept well covered We use a padded jacket which closes in the front, then wrap the legs and cover the abdomen with a blanket after the patient has been put on the fracture table and before the actual

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[1] Rauhs Heilen die Frakturen des Tabikers?, Klin Med *1* 410, 1946

operation is begun The back is covered by a large piece of cloth placed over the pelvic and thorax supports after they had been padded and before the patient was placed on them This covering of the back is important, since it sometimes happens that the patient perspires during reduction and during operation and then, if his back is uncovered, may become chilled by loss of heat of evaporation from that large skin surface Pneumonia may result We have been careful always to protect the patient from chilling in the well over 700 cases in which we have used extra-articular nailing for femoral neck fracture and have never had a single case of pneumonia among them despite the fact that we never use prophylactic penicillin etc [1]

Warming the Bed. Lest the patient should be chilled by being put into a cold bed, we put a heat-cradle under the covers during operation so the bed is thoroughly warmed to receive him We have had electrical outlets installed in the corridors and in the operating rooms to allow easy attachment of these "bakers"

Application of the Foot Slings. While the patient is still in bed, his feet are very well padded, particularly over their dorsa, with cellulose or wadding and then the foot slings are snugly applied. If the padding is inadequate the patient will complain of pain

Checking the Screw Traction Apparatus. Before the patient is put onto this screw traction fracture table, the surgeon should check the apparatus itself to be sure that all is in order (fig 1700) and then should see to it that the table is placed exactly as he desires it in the operating room

Padding the Pelvic Support. Padding for support of the sacrum is particularly important because many of the elderly patients sustaining femoral neck fracture are thin *Two* 2 5 × 36 × 36 cm stitched pads are put on the pelvic rest, for if only one such pad is used the patients often complain of pain there during operation, become restless and squirm about A warm cloth is placed over the pads and the thorax support

Display of Roentgenograms and Skeleton. The original roentgenograms, not sketches, are displayed so that the surgeon can always refer to them during the reduction and the operation The operating room supervisor is in our hospital responsible for having the pelvis and femora from a skeleton also displayed for reference purposes

Placing the Patient on the Screw Traction Table. When the traction table has been checked, the patient warmly covered and the foot slings applied, the traction table is adjusted to the height of the bed Then the patient together with the thigh splint and the weight traction is moved over onto the traction table, care being taken to hold the involved limb in internal rotation, and the perineal post is set in place While slight longitudinal traction is applied and the limb held in internal rotation, the weight traction and the thigh splint are removed The feet are held with the heels about 70 cm apart and both limbs are internally rotated about 40° to 60°, but no longitudinal traction is applied

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[1] Koch, F W Sind postoperative Pneumonien vermeidbar? München med Wchnschr 94 2569--2574, 1952

Then the feet are secured to the foot plates with the slings and are carefully bandaged from heels to toes Strong longitudinal traction must be avoided in order that one not bring about a valgus position at the fracture site which could be corrected only with difficulty The amount of traction can easily be checked by slipping a finger down between the perineal post and the part of perineum against which it impinges While the surgeon fixes the feet to the foot plates, an assistant wraps the sound limb to the hip and the involved limb to the knee with the specially prepared wadding bandages The wrists are padded with cellulose or put in padded cuffs and are suspended at about shoulder level from an overhead frame which is itself within the patient's reach

The pelvis must lie exactly horizontally and at right angles to the long axis of the body, being neither tilted nor rotated Symmetry in the position of the lower limbs and pelvis is best checked by walking round the table and looking at the patient from a little distance Both lower limbs should be kept in internal rotation of 40° to 60° in order to overcome the usual 10° to 15° anterior angulation of the fractured neck and to bring the femoral neck into at least the coronal plane of the trunk (figs 1705—1709) The sound-side limb must be held in corresponding internal rotation to preserve the symmetry of the patient's position if only the sick-side limb is internally rotated the anterior angulation is generally not corrected but rather the sick side of the pelvis is simply lifted while the angulation at the fracture site remains unchanged If there is arthrosis of the knee, longitudinal traction is painful In such case the knee can be supported by a knee prop attached to the longitudinal bar of the traction table and pads can if needed be fixed to this in order to hold the limb in firm internal rotation (fig 1700 a)

Locating the Center of the Femoral Head. The point on the anterior aspect of the hip corresponding to the center of the femoral head can be located because of its relation to neighboring bony prominences If a line be drawn joining the pubic tubercle (1 5 cm lateral to the symphysis pubis) and the anterior superior iliac spine, the center of the femoral head corresponds to a point 2 cm caudolaterally to the center-point of that line That point, as well as the course of the palpable femoral artery, should be marked on the skin with iodine or similar solution In the markedly obese patient with a large and pendulous panniculus adiposus, one must retract that excessive soft tissue cranially with broad adhesive plaster in order to allow easy location of the inguinal ligament

Placing the X-Ray Tubes (figs 1700—1703) The stronger tube or shock-proof tube is placed between the lower limbs near the sound-side knee with its central ray horizontal and directed across the fractured femoral neck at right angles (fig 1703) The tube should not be placed too near the groin on the involved side, since then there is too much enlargement of the neck in the roentgenogram together with loss of sharpness resulting from umbra Moreover, since the exposure to the X-rays follows the inverse square law, one tends to avoid such X-ray burns as reported by Jerusalem if one keeps the distance from tube to tissue as great as possible One gains, then, in both quality of image and in safety to the patient Unnecessary dispersion of the

primary ray can be avoided by using a long cone of about 30 cm. length and 11 cm diameter (fig 1700, 1702)

The stand of the weaker (or the non-shockproof) tube is placed on the sound side of the patient and as far cranially as possible in order to leave room for the instrument nurse on that side of the table The central ray of this second tube should be exactly vertical and centered on the marked center of the femoral head, and it should be confined by a long cone The distance

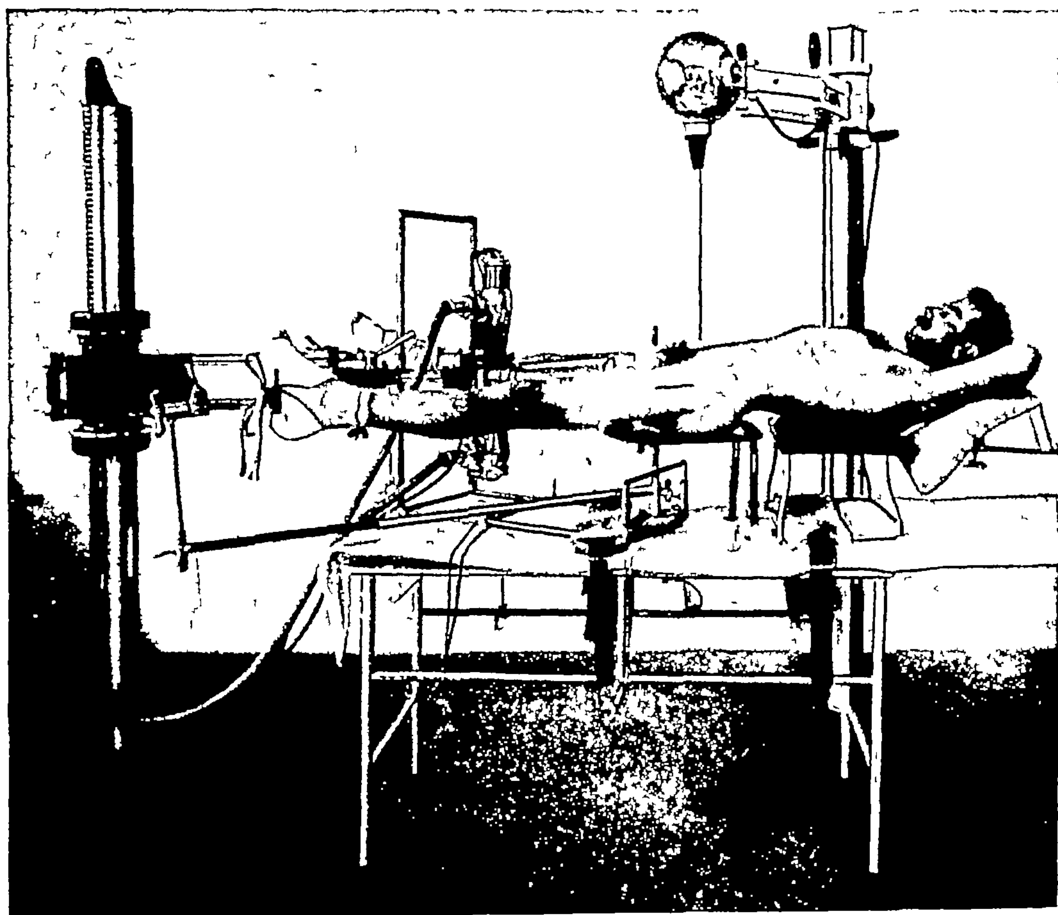
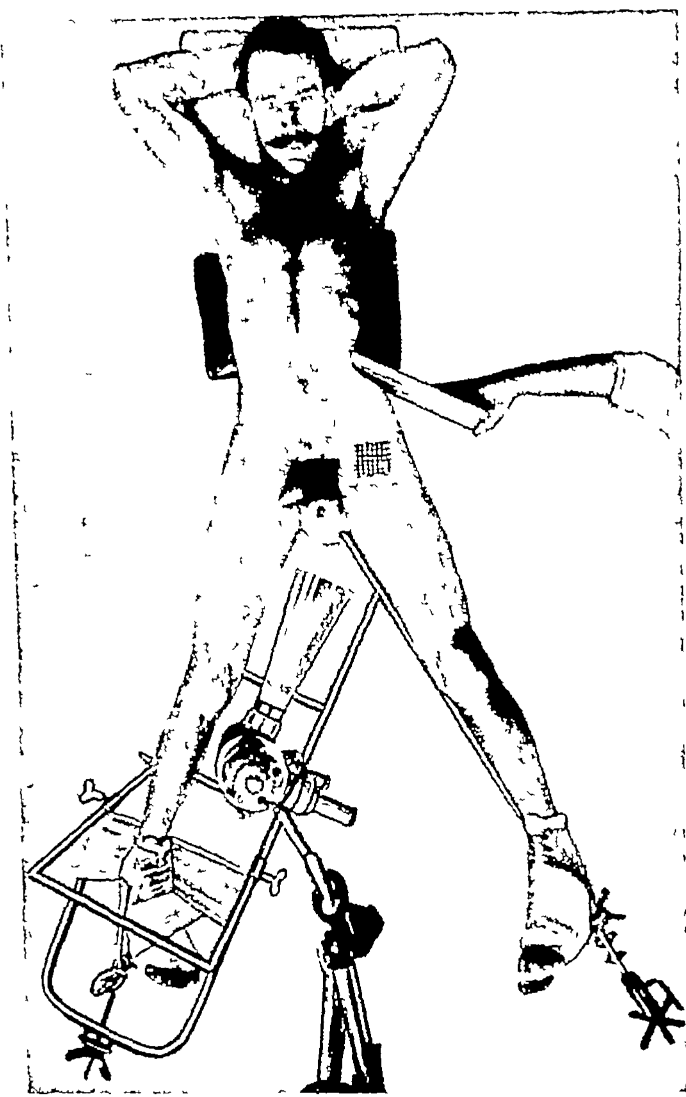


FIG 1701 —Lateral view of patient and the two X-ray tubes The line of incision is marked It lies distal to the greater trochanter, at the junction of the anterior and lateral aspects of the thigh

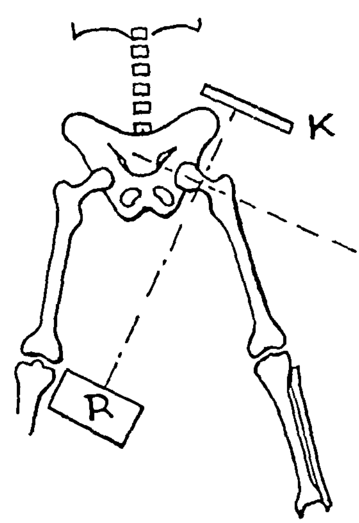
between tube and skin should be at least 55 to 60 cm , and the position of the tube must be precisely vertically above the center of the femoral head This latter is particularly important, since oblique projection, especially in obese patients, may cause the guide pins to appear to be displaced as much as half the width of the femoral neck from where they actually are. If roentgenograms are taken and distorsion of this sort is recognized, the central ray must be re-directed and the roentgenograms repeated

If the stand for the tube to be used for the A-P projection is so low that the tube-skin distance is inadequate, it must be placed on a platform of some

sort Too short a distance causes unsatisfactory enlargement of the femoral head image, increases the irradiation dosage to the ventral skin and threatens to some extent the aseptic operating conditions. In any case, the cone should be covered with a sterile slip of some sort Both X-ray tubes should then be



1702



1703

FIG 1702 Anterior view of patient with X-ray tube arranged for the lateral view The lower limbs are abducted so that the heels are 70 cm apart, and both lower limbs are equally rotated inward The cassette firmly pressed in just above the iliac crest and below the arch of the ribs lies parallel with the femoral neck and vertical to the central ray Jeschke's wire grid is fastened to the front of the hip with two strips of adhesive plaster

FIG 1703—Sketch re figure 1702 The central ray is at right angles to the axis of the femoral neck and the cassette The cassette lies parallel with the femoral neck

fixed to the operating table and to the floor so that all the films taken during operation are taken from precisely the same points This avoids apparent differences which might actually be due merely to shifted positions of t

tubes, and it allows exposures to be made in the two projections in rapid succession

Placing the Wire Grid. When the center of the femoral head has been located and the two X-ray machines have been properly placed, Jeschke's wire grid is placed on the skin of the ventral aspect of the hip region (figs. 1696, 1702, 1720, and page 1243) The most medial and most cranial enclosed square should be placed on the iodine spot marking the center of the femoral head, and the craniocaudal wires of the grid should parallel the long axis of the

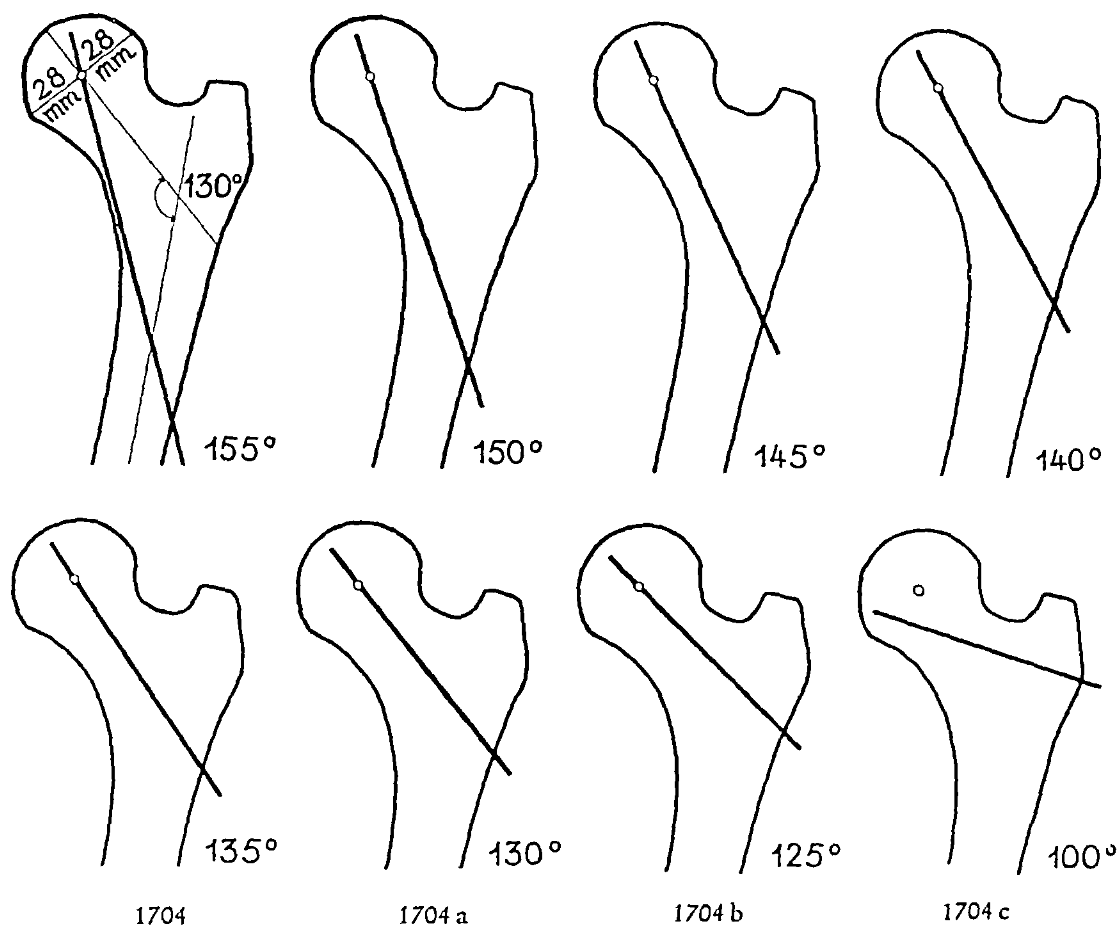


Fig 1704, top—If the guide wire is inserted at an angle of 155°, the three-flanged nail may damage vessels in the cranial part of the femoral head (figures 1564 g, h) This may lead to partial necrosis of the head

Fig 1704 a, top—Insertion of the guide wire at an angle of 150° involves the same danger as with an angle of 155°

Fig 1704 b, top—Insertion of the guide wire at an angle of 145° reduces danger of necrosis

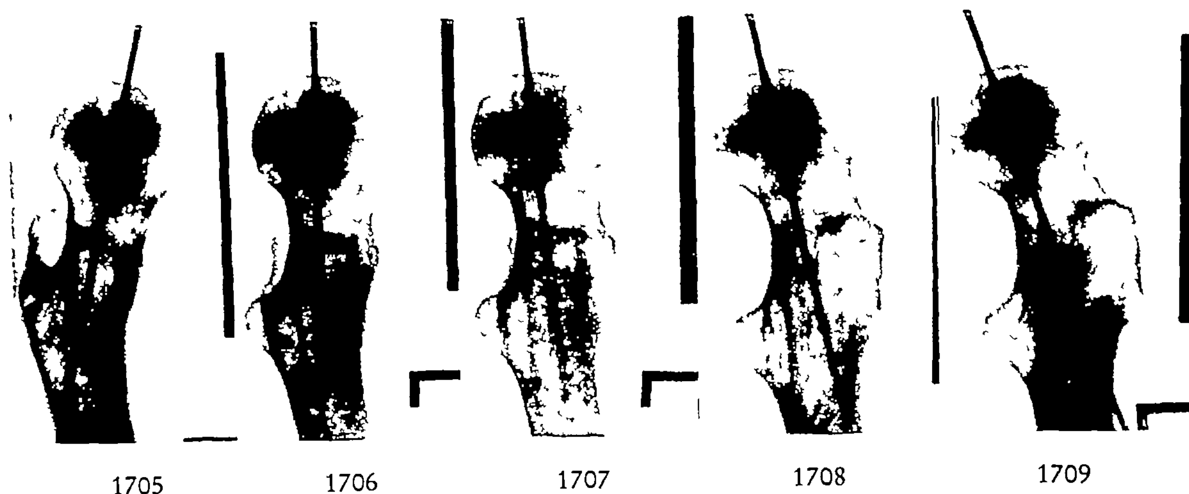
Fig 1704 c, top—With a wire angle of 140°, conditions are the same as in figure 1704 b

Fig 1704, bottom—At an angle of 135° the guide wire lies near the optimal place

Fig 1704 a, bottom—The optimal position of guide wire and three-flanged nail are achieved at an angle of 130° If necrosis of the head nonetheless occurs, the stem of the endoprosthesis can easily be introduced into the nail track

Fig 1704, bottom—At an angle of 125° the guide wire lies near the optimal place

Fig 1704 c, bottom—With an angle of 100° there is danger that the three-flanged nail or a screw might break with weight bearing



FIGS 1705–1709—show lateral roentgenograms of the proximal end of the femur with guide wires placed exactly in the middle of the neck and a lead mark in the middle of the lateral side of the thigh The pictures were taken by Jeschke with the use of a water-level (figure 1695) The pictures are turned 90° so that the metal plate of the water-level appears at their right margins

FIG 1705 —Lateral roentgenogram of the femoral neck with a wire inserted in its long axis The insertion hole in the femur is marked by a small piece of lead The ventrally placed metal strip shown at the right margin of the picture is here vertical It is exactly horizontal in the recumbent patient In this picture the femur lies in mid-rotation, so the physiological 13° anteversion of the femoral neck relative to the shaft of the femur is shown The insertion hole in the femur is projected dorsally because of rotation One-third of the greater trochanter is projected dorsal to the femoral neck The contours of the femoral head are symmetrical Compare with figure 1725 a

FIG 1706 —The femoral neck with the femur rotated internally 13°, compensating for the physiological anteversion The long axis of the femoral neck lies in a coronal plane The insertion hole of the wire lies in the projected middle of the femoral shaft The head sits symmetrically on the neck The greater trochanter projects beyond the neck a little, both dorsally and ventrally The lesser trochanter projects from the dorsal side of the femur Compare with figure 1725

FIG 1707 —The femoral neck with the femur internally rotated through 18° The normal 13° anteversion of the femoral neck has been overcome, the axis of the neck now being retroverted 5° The shadow of the head protrudes a bit more dorsally than ventrally, the greater trochanter is almost entirely hidden by the shaft and neck The lesser trochanter protrudes slightly more prominently than in figure 1706, and the insertion hole for the wire is projected a bit more ventrally

FIG 1708 —The femoral neck with the femur internally rotated through 23° (13° plus 10°) There is, then, 10° apparent retroversion of the femoral neck The head projects much more dorsally than ventrally The lesser trochanter appears even more prominently The insertion hole for the wire lies at the junction of the middle and ventral thirds of the shaft shadow

FIG 1709 —The femoral neck with the femur internally rotated through 33° (13° plus 20°), 20° apparent retroversion of the femoral neck The asymmetry of the femoral head relative to the neck has increased and shadows of the greater and lesser trochantres are still more prominent The insertion hole for the wire is projected far ventrally

femoral shaft (fig 1718) The grid is then fixed to the skin with two small pieces of adhesive tape On the A-P roentgenogram showing this grid superimposed in projection on the hip we can select points exactly indicating the axis of the femoral neck in the coronal plane

First Roentgenograms. The cassette for the A-P projection is slipped into the space beneath the wooden pelvic support (fig 1700) An adjustable ledge inside the space serves to hold the cassette parallel with the femoral shaft and to ensure ample view of the joint-space as well as of the trochanteric region During operation the cassette can easily be brought into the same position

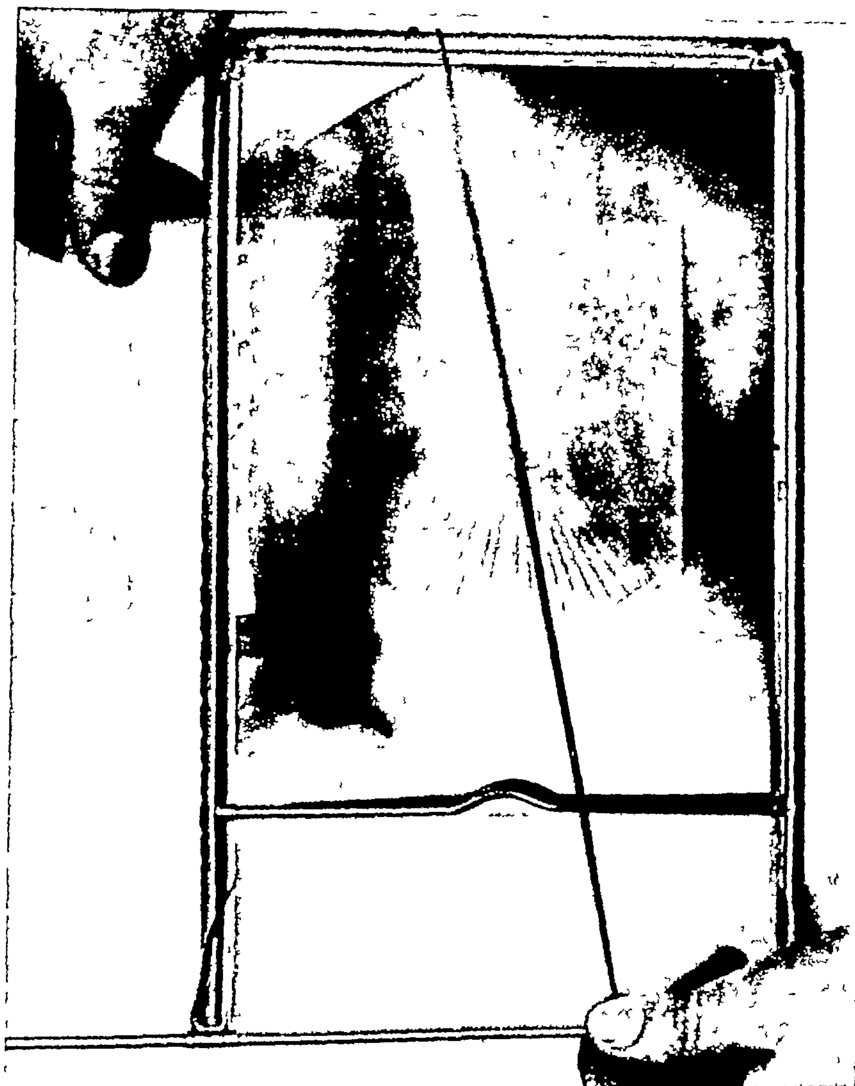


Fig 1710 —Lateral roentgenogram of a medial fracture of the femoral neck, held in a frame At the right margin of the film a white line is seen corresponding to the metal plate of the water-bubble level (figs 1694, 1695) by means of which the cassette is positioned exactly horizontally The black line is a rubber band stretched across the film frame through the center of the femoral head and in the long axis of the neck and the shaft of the femur The protractor rule shown in figures 1711 and 1712 is placed against the film with its straight lines parallel with the white "level" line on the film This shows here a relative dorsal deviation of the femoral neck axis of 11°

for all further roentgenograms without disturbing the sterile drapes If the first A-P roentgenogram shows the wire grid to be incorrectly placed, it should be removed and positioned anew Then the A-P view is taken again



FIG 1711 —Sketch re figure 1710 The dorsal deviation of the rubber band from the center line of the protractor amounts to 7° Then the guide-wire will be drilled in from the lateroventral side in a mediodorsal direction The guide pin is shown projecting into the femoral head ventrally, and the guide needle on the lateral side of the femur is seen distal to lesser trochanter

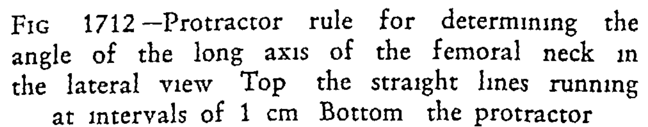


FIG 1712 —Protractor rule for determining the angle of the long axis of the femoral neck in the lateral view Top the straight lines running at intervals of 1 cm Bottom the protractor

A water level is used for the *lateral X-ray* (figs 1694, 1695, 1721) to determine the position of the fragments and the direction of the long axis of the femoral neck in relation to the horizontal plane The cassette is first pressed in between the arch of the ribs and the iliac crest, then its outer border is moved caudally until the cassette lies parallel with the femoral neck and vertical to the central ray (figs 1702, 1703) Counterpressure should be exerted from the other side of the patient to avoid moving of the pelvis when the cassette is being pressed in The cassette should not be pressed towards the arch of the ribs in a mediocranial direction, i e, parallel with the femoral neck, lest it might displace cranially the adjoining skin, the wire grid and later the guide pins

Shortening of the fragments or a varus angulation can usually be corrected by increase of the longitudinal traction on both legs With a fracture line lying in the sagittal plane (Pauwels type III) a valgus position of the fragments sometimes occurs though the shortening remains unchanged This lateral displacement may be left (figs 1728, 1729)

Correction of a *valgus deformity* is much more difficult than that of a varus deformity If it cannot be corrected by impaction, longitudinal traction should be decreased and the limbs rotated externally Then a blanket should be slung round the proximal part of the injured thigh and a second blanket round the pelvis Lateral traction is exerted with the first sling, counter-traction with the second sling Lateral traction can also be exerted on both thighs simultaneously Then both limbs are again rotated internally

A persistent anterior angulation is corrected by increasing the internal rotation of both limbs

If the distal fragment is displaced posteriorly, it should be lifted anteriorly by manual pressure A pad or a folded towel is placed below the trochanteric region to prevent redisplacement

Repeating the First Roentgenograms If the new roentgenograms do not yet show good position of the fragments, manipulation must be continued until A-P and lateral views show satisfactory reduction This may prove difficult and may take quite some time

The operation must not be started until accurate reduction has been achieved, since good alignment is indispensable to good healing

Determination of the Axis of the Femoral Neck. The long axis of the femoral neck must be determined in both planes as accurately as possible so that the guide wire can be driven in properly without loss of time from false starts

Two points serve to determine the femoral neck axis in its frontal plane, i e, the center of the femoral head and the point of intersection of the long axis of the femoral neck and the lateral cortex of the femur (figs 1720, 1722) This latter point also indicates the place of insertion of the wire The course of the femoral neck axis in the other plane can be determined from the lateral roentgenogram by measuring the angle between the femoral neck axis and the shadow of the metal plate of the water-level (fig 1711)

Location of the Femoral Neck Axis in the A-P View and Insertion of the Guide Pins or Needles When the A-P and lateral views show good positions of the fragments, the center of the femoral head is determined in the roentgenogram by bisecting its diameter (fig 1704 a) Its diameter is usualy from 54 to 60 mm A transparent ruler is then placed on the A-P roentgenogram showing the wire grid (fig 1718) The edge of the ruler is laid on the center line of the femoral neck and head This is marked by scratching the surface of the wet film Then on the roentgenogram the point of intersection of the grid lying at the center of the head and the point at the intersection of the ruler with the lateral cortex of the femur are determined and counted out The line connecting these two points of intersection runs in the axis of the femoral neck and should form an angle of 125°—135° with the long axis of the femoral shaft (fig 1704—1704 b) In fig 1720 the center of the femoral head lies in the superolateral corner of the second square counted from above and medially The point of intersection of the femoral neck axis with the lateral cortex of the femur lies in the superomedial corner of the second square counted from below and laterally These two points are marked on the skin with iodine Ventral to the center of the femoral head the sterile pin 8—10 cm long and 1 5 mm thick with the metal head (figure 1678 and page 1243) is stabbed vertically into the femoral head and hammered 1 cm into the bone The exactly vertical insertion of this pin is checked by two observers, one of them standing near the head or the feet of the patient, the other standing at the sound side of the pelvis The pin must not be inserted too far medially lest it should puncture the femoral artery The metal indicator is set on this pin to facilitate the insertion of the guide wire A second pin 10 to 15 cm long or an injection needle is inserted laterally and caudally to the first pin at the point indicated on the roentgenogram by intersection of the ruler with the lateral cortex of the femur (fig 1720) Special care must be taken to insert this long pin exactly vertically The pin should be so long that it almost perforates the skin at the posterior side of the thigh lest it become displaced by operative exposure of the bone To determine its length the diameter of the thigh is measured At the point where the pin touches the bone, the notch for the guide wire is later cut In the lateral view this pin shows the level of the point of intersection of the femoral neck axis with the femoral shaft, which is necessary for determination of the femoral neck axis in that lateral view (figs 1711, 1715, 1721, 1723)

Second Roentgenograms As soon as both guide pins have been inserted, new anterior and lateral roentgenograms are made to see whether the pins are placed correctly (fig 1720, 1721)

The water-level (figs 1694, 1695) is used again with this lateral view to determine deviation of the femoral neck axis from the horizontal

Location of the Femoral Neck Axis in the Lateral View. It seldom lies horizontally In the lateromedial direction it usually deviates dorsally to some degree (fig 1707—1709) and only rarely ventrally (fig 1705) Therefore, surgeons who always insert the guide wire horizontally, viz , parallel with the operation table, have often pierced the ventral quarter of the femoral head

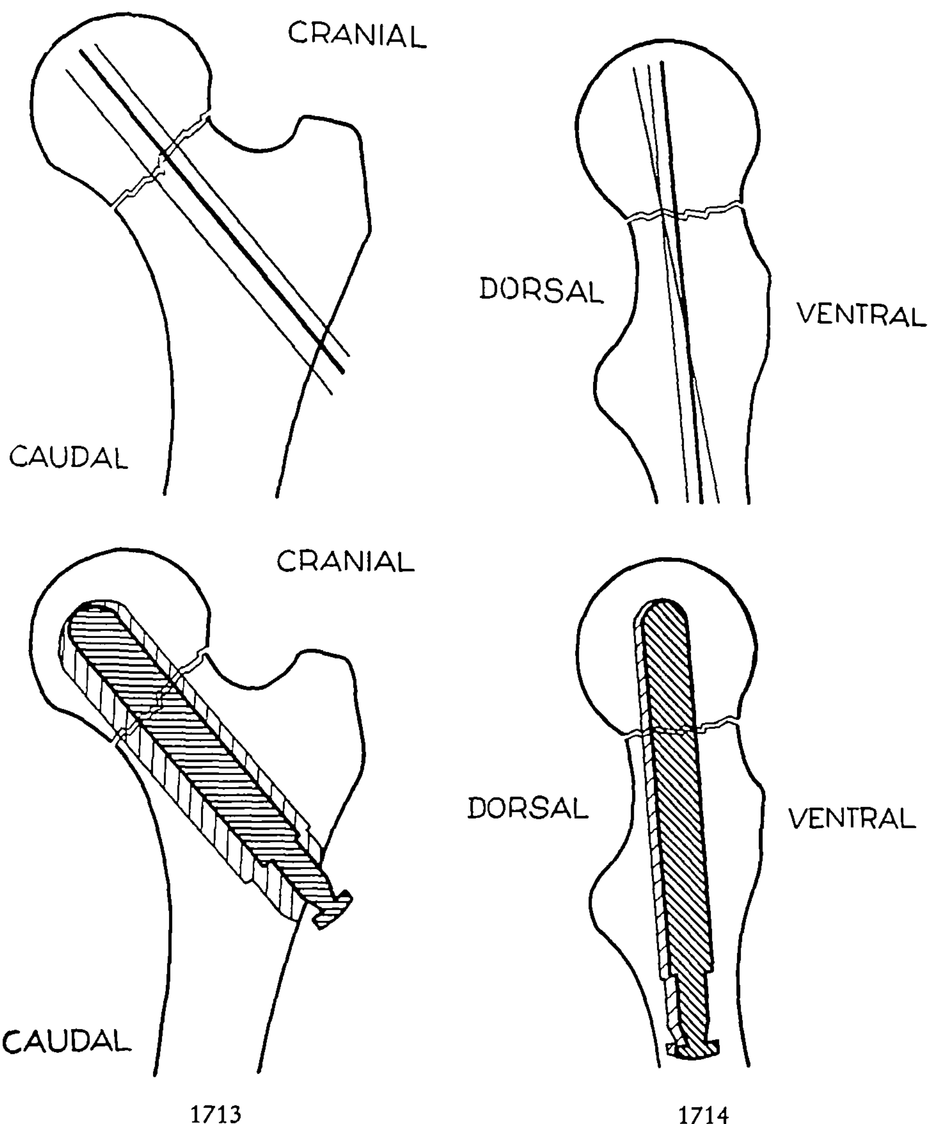


FIG 1713, top — Frontal sketch of the proximal end of the femur The heavy line indicates the optimal position of the guide wire, exactly through the center of the femoral head Shaft and femoral neck form an angle of 130° The two thin lines show the upper and lower limits of the area within which the guide wire may satisfactorily be inserted The distance of the wire from the middle of the head should never exceed 5 mm cranially or 8 mm caudally

FIG 1714, top — Lateral sketch of the proximal end of the femur in 5° internal rotation (compare figure 1707) The heavy line indicates the optimal position of the guide wire exactly in the center of the neck and slightly ventral to the center of the shaft of the femur The light parallel line shows the extreme acceptable dorsal position for a guide wire The wire should never be ventral to, and should never be more than 8 mm dorsal to, the center of the head The wire may also be drilled obliquely from the lateroventral aspect of the femoral shaft in a mediodorsal direction

FIG 1713, bottom — The darkly-shaded area indicates the optimal position of the nail exactly in the center of the femoral neck The lightly shaded area shows the acceptable cranial and caudal limits of the position of the nail The distance between the tip of the nail and the articular cortex of the head should be not less than 8 mm and not more than 10 mm

FIG 1714, bottom — In the lateral view the nail must never lie in the ventral third, because it may then cut through the bone and the head may become displaced In the dorsal third, however, it has a firm hold

and have subsequently noted separation of this part of the head When the lateral view with the shadow of the water-level has been developed, a rubber band is stretched round the film hanger-frame in the long axis of the femoral neck and head Then the big protractor rule with the parallel lines and the degrees (fig 1712) is placed on the film with the center point of the angle-measuring device exactly over the rubber band and with the lines running parallel with the shadow of the water-level Now we can measure the angle between the rubber band and the metal plate of the water-level and thus determine the angle at which the guide wire should be driven in (fig 1715)

The point of intersection of the rubber band with the lateral guide pin shows whether the guide wire should be inserted ventraly (fig 1707) or

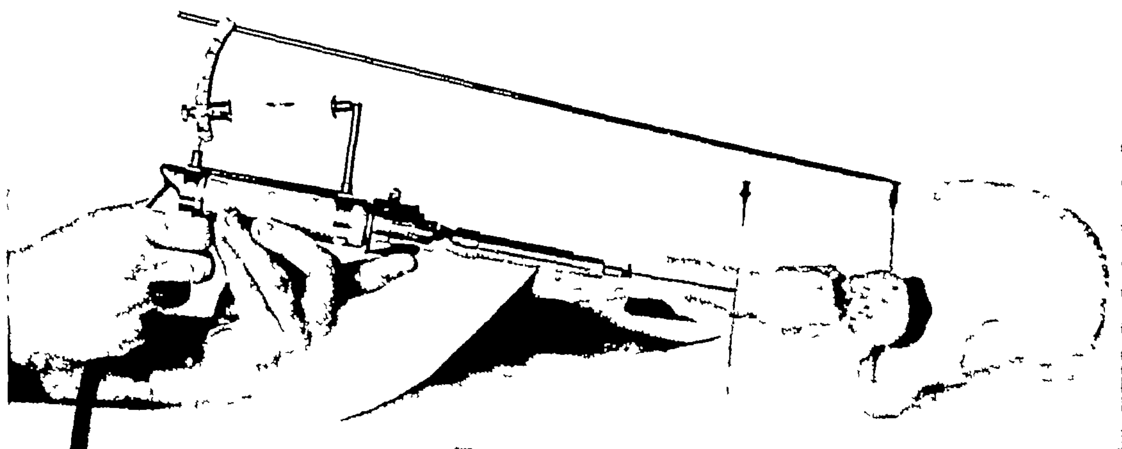


FIG 1715 —Skeleton of the pelvis and the thigh with 12 degrees internal rotation of the femur A mediocranial guide pin is stabbed into the center of the femoral head, a laterocaudal guide pin passes next to the lateral side of the shaft The metal indicator rod runs from the oil-bubble level to the mediocranial pin The point of the guide wire lies next to the latero-caudal guide pin just ventral to the center of the femoral shaft as seen in lateral projection By means of the oil-bubble level arrangement, the drill with the wire guidance apparatus is accurately adjusted to an angle of 12°

dorsally (fig 1705) to the center of the bone The projections of the insertion holes of the guide wires at the lateral side of the thigh in different degrees of external and internal rotation are shown in figures 1705—1709

Removal of the Wire Grid. When everything has been adjusted, the wire grid is removed without displacement of the guide pins

The Operation

Accurate reduction of the fragments and location of the center of the femoral head and the neck axis must always be performed in the same manner The operation itself may be carried out in different ways, i e, through big or small incisions, with or without guidance apparatus and under local or general anesthesia At present we use the following technique

Draping the Field of Operation. After accurate reduction and determination of the femoral neck axis in both views, the skin is painted with iodine and the field of operation is draped with sterile towels

Local Anesthesia of the Lateral Side of the Thigh. Skin, soft tissue and periosteum are infiltrated with 100—150 ml of a 0 5% Novocain solution *through a length of 15 to 20 cm caudal to the greater trochanter and slightly* ventral to the center of the lateral side (fig 1701)

Severance of Skin and Fatty Tissue. Depending on the thickness of the subcutaneous fat, the incision should be 10 to 15 cm long We have given up making smaller incisions which render accurate operation difficult and cause greater damage to the muscles than do big incisions

Toweling-Off the Skin Edges. After severance of skin and fatty tissue and clamping of bleeding vessels, the skin edges are covered with two sterile towels They are fixed not with metal forceps but with three stitches each to prevent disturbing metal shadows in the roentgenograms

Exposure of the Bone. The fascia lata and the vastus lateralis are severed to the bone The long needle inserted at the lateral side of the femur (figs 1711, 1715, 1720—1723) becomes visible Bleeding vessels are clamped but not ligated

Insertion of the Self-Retaining Retractor. After exposure of the bone, the self-retaining retractor is inserted caudally to the pin The joint of the instrument should be placed towards the knee to prevent it from showing in the X-rays It is fixed with a towel forceps The advantage of the self-retaining retractor is that the wound edges and guide pins remain undisturbed throughout the series of roentgenograms and the insertion of the guide wire Furthermore, the surgeon is not hindered by the assistant's hands when aiming and inserting the guide wire *When retractors are removed for the roentgeno-*grams the ventral edge of the skin moves dorsally and the head of the long guide pin 1 to 2 cm cranially When the retractors are reinserted the ventral skin edge moves ventrally and the long guide pin moves 1—2 cm caudally If a surgeon aims at the displaced pin head in inserting the guide wire he will be surprised to see that pin head and guide wire do not coincide on the roentgenogram and that the wire is incorrectly placed

Transverse Insertion of Two Steinmann Pins to Determine the Width of the Femur. To facilitate determining the width of and locating the center of the lateral side of the femur, two Steinmann pins should be inserted after exposure of the bone and the lateral guide pin and after insertion of the self-retaining retractor The Steinmann pins should pass close to the bone at the level of the guide pin The distance between these Steinmann pins shows the width of the bone

Location of the Drill Hole. The drill hole lies next to the long guide pin between the two Steinmann pins *If the femoral neck axis is horizontal*, the drill hole lies in the center of the lateral side of the bone (fig 1706) If the axis rises in a medioventral direction the drill hole appears to lie dorsally (fig 1705), and if the axis drops in a mediodorsal direction the drill hole appears to lie ventral to the center of the lateral side of the femur (figs 1707, 1708)

Cutting a Notch With the Gouge. After determination of where the drill hole should be, a notch is cut out there with a small gouge (fig 1688) The

gouge is first inserted vertical to the bone close to the long guide pin and driven in a short way Then it is inserted 1 cm caudal to this place and driven in obliquely to the bone surface in a mediocranial direction, so that a shallow notch results which perforates the cortex of the femur If the notch is cut too far dorsally a flange of the nail may enter the joint, as the dorsal aspect of the femoral neck is concave and only the ventral aspect of the neck is straight (figs 1705—1709, 1711)

The insertion of the guide wire *is the most important and most difficult part of the whole operation The location of the three-flanged nail and the result of the whole treatment depend on its correctness* Over 100 different guidance apparatus have been devised for direction of the guide wire At present we use a metal indicator 48 cm long (figs 1659, 1715) and an adjustable oil-level attached to the drilling apparatus (fig 1696—1698, 1715) The Desoutter or Aesculap drill is prepared with the guide wire, the guidance appliance and the adjustable oil-level (fig 1715) The angle measured in the lateral roentgenogram is set on the oil-level (figures 1710, 1711 and page 1267) The guide wire is inserted into the notch previously cut in the lateral side of the femur The metal indicator is attached to the oil-level and connected with a set-screw to the guide pin stabbed into the femoral head (fig 1679, 1715) Then the wire is drilled in After the insertion of the guide wire the

Third roentgenograms are taken to check the position of the guide wire The cassette for the A-P view is put into the tunnel of the pelvic support without disturbing the sterile draping For the lateral view the cassette is put into a sterile slip and held as before (see page 1266)

How deeply should the guide wire be drilled in? It should enter the acetabulum for about 1 to 2 cm This is easy if a 22 cm long guide wire is used which cannot project more than 12 cm from the guidance apparatus With a longer guide wire there is the danger of perforation of the abdominal cavity If the wire is too short and only reaches or barely passes the fracture line, and if it does not exactly lie in the center, the head fragment will usually be tilted by the advancing nail A caudally located nail will displace the head in a cranial direction and cause a valgus position, a ventral nail will tilt the head dorsally and cause antecurvature

Where is the best position for the guide wire and the nail? Guide wire and nail are located best if they are seen in the center of the femoral neck and head in both views The angle between the guide wire and the femoral shaft should be from 125° to 135° in the anterior view, and the distance of the wire from the center of the head should not exceed 4 mm cranially or 8 mm caudally (figs 1713, 1714) If the nail is placed more cranially it may sever vessels running in that region (fig 1564 g, h) Furthermore the head is gripped to a lesser degree by a nail located cranially than by a nail located caudally This must be emphasized, because many surgeons have suggested placing the pin as far cranially as possible in femoral neck fractures of Pauwels' type III But we have never seen the head tilt when using our broad-flanged nail and placing it caudal to the center In the lateral view the guide wire should be located only in the center of the head or dorsally but never in the ventral



1716 October 12, 1946 1717



1718 October 16, 1946 1719

Fig 1716 *Anteroposterior view of medial adduction or varus fracture of the femoral neck in a 72 year old woman who fell on the street Severe lateral displacement, shortening, angulation and rotation*

Fig. 1717 Lateral view re figure 1716 Severe lateral displacement and 70° antecurvature

Fig 1718—Check roentgenogram re figure 1716, after reduction in continuous traction The limb was fixed in the screw traction apparatus (fig 1702) and Jeschke's wire grid was put on Lateral displacement, shortening, angulation and rotation have been corrected Good position of the fragments

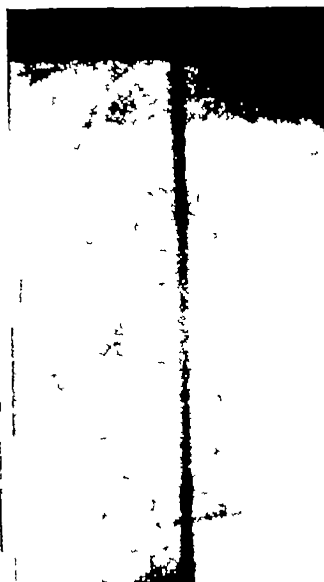
Fig 1719—Check roentgenogram re figure 1717 After accurate reduction the fracture line can hardly be detected Because of internal rotation, the shadow of greater trochanter is superimposed upon that of femoral neck and the lesser trochanter projects dorsally





1720 October 16, 1946 1721





1722 October 16, 1946 1723

FIG 1720—Check roentgenogram re figure 1718, after insertion of the two guide pins whose positions had been selected by means of the wire grid

FIG 1721—Lateral view re figure 1720 At the right margin of the picture is seen the dark (it is, of course, *light* on the roentgenogram itself) shadow of the metal plate of the water-bubble level which was attached to the cassette (figures 1694, 1695, 1713, 1715) The medio-cranial guide pin is seen sticking into the femoral head ventrally

FIG 1722—The guide wire lies exactly in the center of the femoral head The angle between the wire and the axis of the femoral shaft is 135^{0} Caudal to the insertion hole for the guide wire is seen the shadow of the self-retaining retractor

FIG 1723—Lateral view re figure 1722 The guide wire lies slightly dorsal to the center of the head and ventral to the center of the femoral shaft

half (fig 1714) If the nail lies in the ventral half the femoral head may become separated, a danger that exists especially with anterior angulation of the fragments







1724 November 14, 1946 1725 1725 a







1726 February 8, 1948 1727 1727 a

FIG 1724—Check roentgenogram re figure 1722, after insertion of the three-flanged nail It lies in the center of the femoral head and its tip approximates the articular cortex of the head within 8 mm

FIG 1725—Check roentgenogram re figure 1723 The three-flanged nail lies exactly in the center of the head and slightly ventral to the center of the femoral shaft

FIG 1725 a—With 30° external rotation of the femur the nail appears to have been inserted from the dorsal aspect of the femur (cf fig 1709)

FIG 1726—1727 a—Check roentgenograms re figures 1724—1725 a, fourteen months after operation and three months after removal of the nail Fragments healed by bony union in very good position The nail-track is still visible

The guide wire should never be drilled through the greater trochanter (fig 1704 c, bottom), since the femoral head may become displaced with a nail inserted in this way and the nail itself may break under persistent flexion stresses (fig 1778 d, e)

Reinsertion of the Guide Wire. If the position of the first guide wire is unsatisfactory, its deviation is measured on the roentgenograms Then a new notch is cut into the bone and a new guide wire is inserted If the angle of the guide wire is a good one in both views, the wire only lying too far caudally or cranially, the new wire is best drilled in with the hand drill (fig 1692)

Repeating the Third X-Rays. They are taken in the manner described on page 1266 The insertion of the guide wire and the making of roentgenograms in both projections must be repeated until a satisfactory position of the wire





1728, April 22, 1937 1729, September 11, 1937

Fig 1728 —Anteroposterior roentgenogram taken at the end of operation showing a femoral neck fracture with extraordinarily steep fracture line (Pauwels III) in a 29 year old man who fell and abruptly twisted the limb when skiing Slight lateral displacement, good alignment, the fragments are in good contact at the cranial part of the fracture line

Fig 1729 —Check roentgenogram re figure 1728, $4^1/_2$ months later Bony union across the fracture line The gap at the caudal side has filled with callus These fractures will always unite if they are reduced well and early enough and are immobilized without interruption Healing takes no longer than in fractures with less steep angulation of the fracture line But it is important that the nail be inserted caudal to the center of the femoral neck so that it can grip as much as possible of the head This nail should have been inserted a bit more steeply The patient was allowed up with two canes 14 days after operation He could walk with one cane after three weeks and without a cane after five weeks After six weeks he could again swim, after three months he could play tennis, and after four months he started horse-back riding again

is achieved, as shown in figures 1713 and 1714 **The best reduction of the fragments is useless if the guide wire and nail are not located well.** We have seen hundreds of patients operated on elsewhere for femoral neck fractures in whom bad results, e g , separation of the femoral head, breaking of the nail etc , were due to mal-position of the nail

Drilling the Cortical Bone. To prevent fragmentation of the cortical bone, the 8 mm thick cannulated trephine (fig 1678 and page 1244) is attached

to the drill and threaded over the guide wire Then the compact bone is trephined The trephine is cooled by water slowly but continuously squirted on it

Cutting a Caudal Longitudinal Notch. After trephination of the cortical bone, a longitudinal notch 1 cm long is cut with a chisel (fig 1689) into the bone at the caudal end of the hole A three-flanged chisel shaped like the three-flanged nail can also be used

Determination of the Length of the Nail. If the guide-wire lies well, the distance of the wire from its insertion into the bone to the surface of the femoral head is measured with a ruler By subtracting 20 to 25 mm to allow for distorsional enlargement, the correct length of the nail is determined In the beginning we used too long nails in four patients because we did not take into account the enlargement of the bone as projected onto the film To catch possible mistakes by the instrument nurse, the surgeon should check the length of the nail to be used by measuring it with the sterile metal ruler (fig 1693)

Insertion of the Nail. It is threaded onto the guide wire in such a way that a flange comes to lie in the longitudinal notch cut caudally to the guide wire In this position the nail has its best carrying capacity Then it is driven into the bone with the cannulated driver (fig 1684) The driver should be pressed caudally towards the femur lest the nail might move cranially and break the cortical bone The wire may also bend After every two or three hammer blows the driver should be taken off and the surgeon should check to see that the wire is not moving inward together with the nail This may happen if the wire has been caught by the nail The wire may in such case be unintentionally driven into the abdominal cavity As soon as one sees that the wire moves with the nail, one must extract the wire Unusually strong resistance noted with insertion of the nail generally indicates that the wire has bent We must not simply carry on with brute force in such a case, but must rather recognize the possibilities and must take roentgenograms in both planes (figs 1744, 1746) The bent wire can only be extracted when the nail has been withdrawn for 0 5—1 cm with the nail-extractor shown in fig 1685 If it cannot be extracted in this way, wire and nail must be withdrawn together Such a complication will seldom occur if wires of 2 2 mm diameter and of appropriate temper are used The nail is driven in until its head approaches to within 1 cm of the lateral cortical surface It can then be withdrawn easily later, if necessary If the head of the nail is driven in right up to the bone, withdrawal with the older nail extractor (fig 1685) proved difficult because it had trouble gripping the head Sometimes the cortical bone had to be chiselled away This was a waste of time and impaired the stability of the bone With the extractor device as shown in figures 1678 and 1679, however, the nail can be withdrawn easily even when it is driven in right up to the bone

Fourth Roentgenograms. The nail's position is determined by new A-P and lateral roentgenograms The tip of the nail should be within 8—10 mm of the surface of the femoral head If the roentgenograms show a greater

distance, the nail must be driven in more deeply to prevent a subsequent separation of the femoral head (figs 1755—1759) Special care should be taken not to drive the nail in too deeply or to perforate the femoral head, since the vessels of that region (fig 1664 g, h) may be cut by the flanges of the nail and circumscribed necrosis develop A nail inserted for too short a distance can easily be driven in more deeply, but a nail driven in too far may cause irreparable damage to the vessels, no matter whether or not it is pulled back afterwards

Removal of the Guide Wire. When the roentgenograms show satisfactory position of the nail, the wire is withdrawn with strong pliers (fig 1690)

Repeating the Fourth Roentgenograms. If the nail has been driven in deeper or withdrawn, both views should be repeated to check the new position This whole process must be repeated until satisfactory position has been achieved

Impaction of the Femoral Neck. Formerly we impacted all femoral neck fractures with the impaction punch (fig 1683) with 20 strong hammer blows Now we impact the fragments only in the rare cases of diastasis visible on the roentgenograms Longitudinal traction must be released prior to impaction We have the impression that some cases of necrosis might have been caused by too strong impaction We therefore use only 5 to 6 rather gentle blows with the hammer even in cases with a diastasis

Fifth Roentgenograms. In the rare cases in which impaction has been performed, new A-P and lateral roentgenograms are made

Prevention of Extrusion of the Nail. Extrusion of the nail has often been observed Many surgeons insert a metal pin into the bone, caudal to the head of the nail Other surgeons use a screw put into the bone through a hole in the head of the nail Since there are more than a hundred different alloys of stainless steel, there is the probability that the nail and the accessory pin are made of different kinds of metal In this case, electrolytic processes will cause damage to the bone near the head of the nail

With our new type of nail (figs 1680, 1681) whose flanges are provided with sharp-edged steps just below the tapering part near the head, extrusion of the nail has rarely been observed In these rare cases the nails slipped out only because they were not driven in deep enough and the sharp-edged steps in the flanges failed to take a firm hold in the bone

Wound Excision. If muscle fibers have been torn or severely contused at operation, they should be excised Bleeding vessels are clamped When the clamps have been left on for some minutes, however, it is often no longer necessary to ligate the vessels

Insertion of a drain is rarely necessary In the case of severe bleeding from the hole of the nail, a rubber drain is inserted through a separate incision 5 to 6 cm dorsocranially from the operation wound The drain should lie on the bone and close to the head of the nail and should be stitched to the skin

Wound Closure. The fascia of the vastus lateralis is closed with 5 to 6, the fascia lata with 6 to 8, fine sutures Then suture of the skin follows

Administration of Antibiotics. As we have seen no infection after femoral neck nailing since 1947, we usually refrain from the use of penicillin or other antibiotics

Bandage. After suture of the skin the wound is compressed firmly from both sides to evacuate blood which might have escaped from the canal of the nail during closure of the wound Then the skin is painted with skin adherent 1 to 2 cm from the wound edges and a small sterile gauze dressing with balsam of Peru is fastened to the skin with adhesive tape The drain (if any) is covered with a dressing of its own

Then the sterile drapes are removed, the patient is freed from the traction table, the cotton-wool jacket and the blanket are taken off If the skin is moist from perspiration it is rubbed dry with towels Then the patient is placed on a pelvic support in his warmed bed

After pads have been applied evenly, a spica coxae trochanterica is applied under sufficient pressure A spica coxae inguinalis, which I have sometimes seen applied, cannot exert pressure on the wound The edges of the bandage may nowhere touch the plain skin, lest they should cause undue pressure [1]

Marking the Bandage. If a drain has been inserted, a strip of adhesive tape with the inscription "drain" is put on the bandage to indicate it The day of the accident, the day of the operation and the name of the surgeon are also inscribed

Positioning the Limb. The limb is placed on a cushion We have stopped using the Braun splint since we have observed some cases of peroneal paralysis The forefoot is suspended in a cradle with the Unna's paste dressing which was for this reason not removed before operation

Withdrawal of the Traction Pin The pointed end of the pin is well cleaned with benzine and alcohol and painted with iodine The blunt end is then grasped with the strong pliers and the pin is removed (fig 1690) by traction and rotatory movements Both wounds are dressed with sponges to which a drop of Peruvian balsam has been applied The patient should be taken back to his room well-covered and with his head protected against cold drafts

Raising the Foot of the Bed. To prevent congestion of the blood in the lower extremities with possible thrombosis and embolism, the foot end of the bed is raised 50 cm for 4 to 5 days after operation

Removal of the Drain and of the Compression Bandage If a drain has been inserted it should be removed after 24 to 36 hours The big compression bandage is also removed at that time Only the small dressing with the adhesive tape remains

Removal of the Sutures. The stitches are taken out 8 to 10 days after operation

Treatment of Unstable Fractures of the Femoral Neck

Femoral neck fractures are unstable from the beginning if a wedge-shaped fragment has broken out from the inner arch of the neck (calcar femorale) as in

[1] Bohler, L "Verbandlehre" (in German), figures 89—94, Vienna, Maudrich, 1947

figure 1778 a Fractures of the femoral neck may become unstable in the course of the treatment, e g , by insertion of the nail at too flat an angle (fig 1778 c) All stability is lost in such a case if the greater trochanter breaks The stability is endangered if the nail has been driven in too far cranially or ventrally, as shown in figures 1755—1758 a and 1778 d, and does not grip the head sufficiently Stability is also uncertain in pathologic fractures Some other surgeons have suggested the use of two three-flanged nails in these cases But necrosis of the femoral head usually develops in those cases, as I have seen in patients shown to me or in cases that have been published. Too many vessels are probably destroyed by two nails It is better to attach a plate to the one nail as shown in figures 1879, 1980 It serves well in conditions shown in figures 1778 a—c If, however, the nail has been inserted too far cranially or ventrally, the plate will of course not help In this case stability can only be achieved by new and better position of the nail Prognosis will remain poor, since important vessels have usually been severed by the first nail Two nails serve well in arthrodesis of the hip (figs 1565 e, 1855)

Treatment of Femoral Neck Fractures with Screws

Some authors, as Putti, Godoy-Moreira, Reimers and many others, use screws instead of the Smith-Petersen three-flanged nail The same end-results will probably be achieved, if after accurate reduction the screw is properly inserted and provided the screw has only a short thread which engages just the central fragment If the thread also holds the distal fragment a diastasis will develop, as the fragments cannot approach each other after the inevitable resorption of a small amount of bone from the fracture ends This may lead to non-union or to necrosis of the head

Treatment of Femoral Neck Fractures with Wire Pins

Some surgeons use three or four wire pins instead of a three-flanged nail or a screw It is possible that fewer vessels are hit by this method and that there is therefore less danger of femoral head necrosis On the other hand, Carlquist[1] observed necrosis of the head in 41 per cent of the cases in which fixation was accomlished with three wire pins

Treatment of Fractures of the Femoral Neck with Autoplastic Bone Grafts

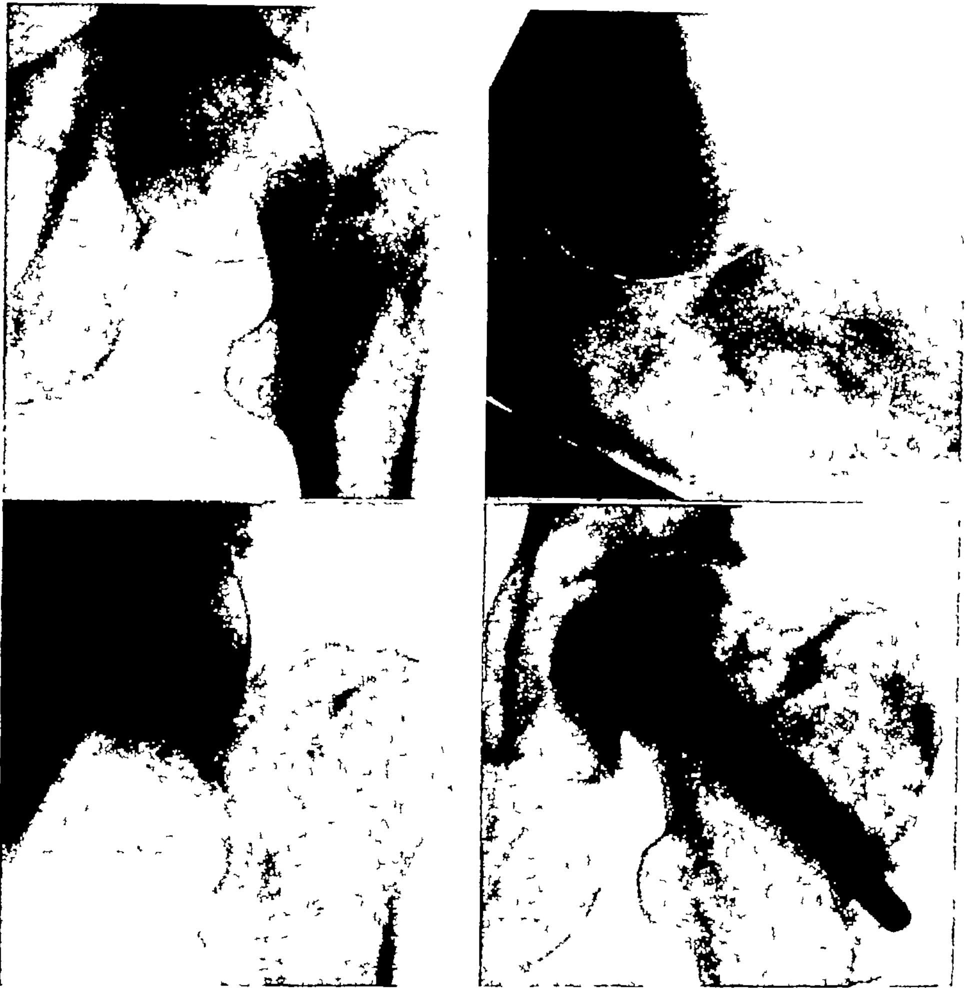
Bado[2] uses autoplastic bone grafts instead of the three-flanged nail and has achieved excellent results in 79 5 per cent of 105 cases, as I could observe myself during a visit to his hospital in Montevideo He reports 5 6 per cent necroses, 9 5 per cent non-unions and 5 6 per cent technical mistakes In his view, closed reduction, transplantation of an autoplastic bone graft, plaster cast and rest in bed for three months constitute the best treatment if the patient's general condition is good With patients in poor general condition

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[1] Carlquist 1947 Acta chir scand *127*, 95

[2] Bado La cura delle fratture del collo del femore con innesto osseo Archivio Putti 2 17—32, Firenze, Edizione Sientifiche, Istituto ortopedico Toscana, 1952

1730 February 13, 1953 1731



1732, February 15, 1953 1733, May 10, 1953

FIG 1730—Medial adduction or varus fracture of the left femoral neck in a 64 year old engineer who was hit on the buttock by a falling machine The contour of the femoral head appears almost as a circle The femur is rotated externally and displaced cranially by half the width of the neck

FIG 1731—Lateral view re figure 1730 The fracture end of the head "faces" ventrally Therefore the head appears circular in the anteroposterior view The femoral neck lies dorsal to the head in this case, whereas in most other cases it is displaced slightly ventrally as in figures 1596 and 1705 The 85° angle between the fragments is open dorsally

FIG 1732—Check roentgenogram re figure 1730, the patient in continuous traction of 10 Kg The femoral head shadow is circular, as its fracture surface faces exactly ventrally The shortening has been corrected The 90° anterior angulation has remained

FIG 1733—*Check roentgenogram re figure 1730 after insertion of a radiolucent acrylic endoprosthesis with metal reinforcement*

FIG 1734—Breakage of the three-flanged nail in a 39 year old female unskilled worker suffering from early tabes On June 21, 1939, when shoveling sand, she suddenly felt a stabbing pain in her left hip and could no longer walk Roentgenograms showed a fracture through the base of the femoral neck Treatment with continuous traction As there were only minimal tabetic symptoms, she was operated on after some consideration on July 12, 1939 She got up on July 26, 1939 On August 1, 1939 she could walk well with a cane and was discharged from the hospital On September 5, 1939, when walking, she felt a sudden pain and could go only a few more steps Roentgenograms then showed the nail had broken The lateral piece of the nail was extracted, since the fracture could not be reduced accurately with traction



1734, September 9, 1939 1735, September 15, 1942

FIG 1735 —Check roentgenogram re figure 1734, three years later The femoral head has slipped out of the socket The femoral neck has been absorbed at both fracture ends and about the lesser trochanter Distal to the lesser trochanter a "shelf" has formed, 4 × 4 cm in size, which is apposed to and supports the femoral head Patient walks with a severe limp but without pain, since she is tabetic



1736 1737 1738

FIG 1736 —Femoral head with normal bony structure ten years after nailing for a medial femoral neck fracture in a 55 year old farmer's wife Accident on September 27, 1927, operation on October 6, 1937 Condition on July 10, 1947, i e, ten years after injury shape and structure of femoral head normal, normal width of "joint space," normal function

FIG 1737 —Moderate changes in a femoral head six years after nailing for a medial fracture of the femoral neck in a 62 year old unskilled worker Accident on January 24, 1946, operation on January 28, 1946 Condition on May 21, 1952, i e, six years after injury slight cystic changes in femoral head and neck, 3 mm wide marginal exostosis at the junction of head and neck, normal width of "joint space", normal function No pain, patient has resumed work

FIG 1738 —Severe changes in a femoral head five years after nailing for a fracture of the femoral neck in a 64 year old housewife Accident on February 14, 1947, operation on February 26, 1947 Condition on May 24, 1952, i e, five years later cysts and sclerosis in the head and neck, but no cortical depression, 3 mm wide marginal exostosis at the junction of the head and the neck and 7 mm wide marginal exostosis from the acetabular lip Pain from time to time Patient can walk for one hour, but limps and uses a cane Hip motion 160°—80°, abduction limited by ¹/₃, rotation is almost nil

he uses a homoplastic graft from the bone bank in combination with a three-flanged nail but without a plaster cast

His technique is as follows·—

(1) Operation after one week, (2) Spinal or local anesthesia; (3) Reduction on the extension table by longitudinal traction, abduction and internal rotation, (4) Application of a lead marker, (5) Exposure of the bone and insertion of the guide wire with simultaneous excision of a graft from the anterior side of the ipsilateral tibia, (6) Insertion of an 11 mm drill over the guide wire, (7) Check roentgenogram when the drill is 8 cm deep, to prevent perforation of the femoral head, (8) Insertion of the prepared graft, (9) Closure of the wound in layers, (10) Plaster cast for three months, (11) Three to four weeks' rest in bed and exercises; and (12) Discharge from treatment after $5^1/_2$ to 6 months

He emphasizes· (1) Accurate reduction, (2) Optimal location of the graft (not too far ventrally, dorsally, cranially or caudally), and (3) Avoidance of perforation of the femoral head

His roentgenograms show accurate reduction in all cases The bone graft has been inserted as a rule at an angle of 130°

We have no personal experience yet with this method Its end-results ar the best I have ever seen The method seems to be worthy of imitation

TREATMENT OF PATHOLOGICAL FRACTURES OF THE FEMORAL NECK

The femoral neck may fracture because of local or general disease without any considerable trauma, e g, in tabes (figs 1734, 1816), metastatic tumor or after heavy irradiation of the pelvis

In tabes nailing should be omitted, because the nail or screw tends to break as shown in figures 1734 and 1735 unless the patient is kept in bed 10 to 12 months postoperatively

In *tumor metastases* a plate should be attached to the nail to ensure stability for some time when the growth progresses

In the *spontaneous fractures of the femoral neck after irradiation therapy*, the varus angulation can usually be corrected even after months by continuous traction with weights up to 15 Kg If normal position has then been obtained, nailing can be performed In a fracture lying far laterally, a plate should be attached to the nail

TREATMENT OF RECENT FRACTURES OF THE FEMORAL NECK WITH EXCISION OF THE FEMORAL HEAD

Since Judet in 1947 published the method of replacement of the femoral head by an acrylic prosthesis in cases of non-union of the femoral neck, necrosis of the femoral head and arthrotic changes of the hip, some surgeons have suggested such replacement of the head also in recent fractures of the neck On visits to different places I have noticed that this has been done many times I would advise against this procedure, as one's own femoral neck is

usually better than an artificial one Besides, we do not yet know how long is the life of such an endoprosthesis in the body The number of published failures is increasing from year to year

What Should Be Done if a Fracture of the Femoral Neck Cannot Be Reduced?

Open Reduction of a Femoral Neck Fracture When a femoral neck fracture could not be reduced, we sometimes tried to accomplish reduction by rotatory movements with the hip and the knee flexed to right angles This manipulation was usually successful but necrosis of the head often developed in these cases We also tried open reduction in these cases Head necrosis and non-union followed also in these cases (figs 1847—1853), because vessels running to the head were sometimes destroyed at operation Therefore we now refrain from manipulation as well as from open reduction and restrict reduction to the method of continuous traction (see page 1270—1275)

Excision of the Femoral Head and Replacement by an Acrylic Prosthesis In gross displacement, as seen in figures 1730—1732, when the fracture ends do not touch, or if the fragments are in contact only by one single edge as in figures 1761 and 1856 c, bony union cannot occur In these rare cases it is best to excise the femoral head as early as a few days after the injury, if the patient's general condition is good, and to replace it by an endoprosthesis as shown in figure 1733

Exercises

After the operation, strong active movements of the toes, the ankle and the subtalar joints must be carried out through their full range from the first day on to improve the circulation in the limb

From the fifth day on, the patient should strongly contract the femoral muscles several times a day (see page 1205) Mobility of the toes, the ankle and the subtalar joints and contraction of the muscles are examined on each rounds

If the temperature is normal and the patient feels well, he starts exercises with the sound leg on the "mountain climber" (Vol I/figs 21, 22) as described on page 1205

On the tenth day he starts exercising the injured leg on the knee flexion apparatus (figs 1574, 1575, pages 1205 and 1207)

In the beginning, the exercises on the "mountain climber" as well as on the knee flexion apparatus should be performed for only five minutes each in the morning and in the afternoon The exercises are then extended by five minutes per session daily, *if there is no discomfort*

I have seen a patient who, contrary to the rule that the patient exercise five minutes only, carried out exercises on the knee flexion apparatus for one hour at the first attempt After a few hours the leg became severely swollen, thrombosis supervened and two days later embolism occurred, to which the patient nearly succumbed

Another patient, contrary to our strict advice, exercised for more than one hour on the knee flexion apparatus Two hours later he had a chill and ran a temperature of 40° C The operation wound became hot and red and broke down after three days

From the eighth day on, the patient should sit up with or without the help of a rope-ladder (Vol I/fig 185) to flex his hips He should also lie flat in the bed for a quarter of an hour daily (fig 1604 d) and should carry out arm exercises (see page 1206) The exercises are inscribed on the blackboards and entered in the charts (see page 1206)

Energetic massage and forceful passive movements must be avoided They can only be harmful, since the joints are irritated by them

Diathermy may be harmful because of the metal in the bone

X-ray irradiation is recommended by some surgeons We advise against it

When to Allow the Patient Up. Here the views differ widely Some surgeons allow weight-bearing only after many weeks or months in order to try to avoid necrosis of the femoral head Since necrosis of the head is only caused by circulatory disturbances, in our opinion it is best if the patient starts exercising and weight-bearing early *provided no pain is felt* Those surgeons who do not allow weight-bearing until much later do not observe necrosis of the head less frequently than do we who allow early weight-bearing Figures 1647—1677 show the occurence of head necrosis in patients who were in bed for months and bore no weight We have shown on pages 1093 and 1123 that head necrosis following pure dislocations of the hip is very rare with early exercises and weight-bearing, perhaps even less frequent than after long immobilization

If no complications have followed the operation, on the fifteenth day an Unna's paste dressing is applied from the web of the toes up to the knee and an elastic bandage is wound round the knee for daytime wear but is removed for the night If there is a general tendency toward swelling, an Unna's paste dressing is applied to the sound leg, too The technique of application and the necessary material is accurately described in "Verbandlehre"[1] This we feel to be our best prophylactic against thrombosis Our fatal cases of pulmonary embolism have occurred before the patients got up After application of the Unna's paste dressings, the patients get up and start walking with the help of two quadripod canes (figs 1635—1638) Three to six days later they usually can walk with two sticks, after three to six weeks they usually require the help of only one stick After six to eight weeks, many patients can walk without a stick After six to eight weeks, active motion of the hip joint and all other joints is as a rule unlimited The patients may bear weight only as long as *no pain* is felt After three to four weeks they can usually be discharged from the hospital The average time of confinement to the hospital in our operated patients (excluding postoperative deaths) amounts to 26 days as against 148 days in earlier years when we used the big plaster spica

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[1] Bohler, L Verbandlehre, Vienna, Maudrich, 1947, pp 74—86
— Sargı bilgisi, Ankara, Milli Egitim Basınevi, 1949, pp 74—86
— Verbandleer, Amsterdam, Scheltema and Holkema, 1950, p 8495
— Manuel de ataduras, Sao Paulo, Pablisher Melhoramentos, 1950, pp 94—107
— Chinese, Shanghai, 1951, pp 61—71
— Nauka o zavojema, Beograd, Medicinska Knjiga, 1951, pp 81—92
— Manuale des bendaggio, Milano, Vallardi, 1952, pp 71—80

Early weight-bearing will not loosen the nail if it has been positioned properly However, the nail will work loose eventually even without early weight-bearing if it has not been positioned properly

X-Ray Checks. The patients are told to report at once for check roentgenograms if pain should occur or if mobility should decrease Apart from this, new roentgenograms should be made every two months at the beginning and every three to six months later on For this purpose it is necessary to keep special files on these patients Many patients show definite bony union only after six months, some patients only after eight to ten months

Should the Three-Flanged Nail Be Removed or Left in Place?

Since we have for years been using only stainless, amagnetic nails which cause no reactions in the body, we usually leave the nail in place permanently

Removal of the Nail Because of Rust Formerly, when we did not always use stainless nails, we removed them after one to two years to avoid complications due to rust Corrosion of the nail (figs 1802—1806) can sometimes be seen in roentgenograms after just a few weeks Small, and later on sometimes extensive, destruction of the bone occurs only after months and even years (figs 1780—1783, 1798—1801, 1832—1837) This destruction of the bone is accompanied by a dragging pain in the low back and in the limb, especially in the knee This pain sets in after a period of well-being of some months and increases slowly, it may become rather severe especially at night if the bone destruction is extensive Motion of the joints decreases and the patient starts to limp Patients who used to walk without complaints become able to walk only with the help of one or two sticks and for only short distances Contractures develop The calcium content in the vicinity of the hip joint decreases With the removal of the nail the nocturnal pain sometimes disappears suddenly and the other complaints may diminish (figs 1798—1801)

Removal of the Nail Because of Head Necrosis If, owing to necrosis of the head with or without established non-union, a three-flanged nail approaches the joint, it should not be removed, since the patient's troubles then increase, especially in the cases of non-union when the femoral neck is thereby deprived of its last support (figs 1847—1856 f) The patients then tend to blame the surgeon who removed the nail for the increasing pain In cases of head necrosis and non-union, a nail that has penetrated the hip joint should be removed only if it is replaced at once by a shorter one or if arthrodesis (see page 1099) or arthroplasty (see page 1102) is performed

Technique of Removal of the Nail. General anesthesia is to be preferred for removal of the nail, since the operation is usually a short and simple procedure The head of the nail usually lies a few centimeters dorsal to the operation scar, since its insertion was carried out with the limb in internal rotation The new incision should therefore lie about 5 cm dorsal to the old scar After severance of skin and fascia, one usually meets a bursa surrounding the head of the nail If the nail is stainless and amagnetic the bursa will contain a clear fluid, but if the steel of the nail is magnetic or if the head of the nail was welded or riveted the surrounding tissue will be brownish or black

Sometimes the nail can easily be withdrawn with a forceps some months after insertion In a case of corrosion as in figures 1802—1806, the space round the nail is so wide that it can even be rotated round its long axis With especially bad material, as was used in the case of figures 1798 and 1799, the cavity round the nail may become as wide as 3 cm On the other hand, in the case shown in figure 1864 the nail was still fixed so firmly about three years after operation that it could be removed only with considerable effort That nail was clean and shiny, showing no signs of corrosion All discolored tissue should be excised with scalpel and scissors, the channel in the bone should be scraped out with a sharp curette In the case of severe hemorrhage from the bone, drainage is performed through an incision dorsal to the operational wound Then after a few deep sutures the skin is closed No vessels are ligated After application of a compression bandage (spica coxae trochanterica,[1] not inguinalis) the leg is placed on a pillow The drain is removed after 24—36 hours

INCIDENTS DURING OPERATION FOR MEDIAL FRACTURES OF THE FEMORAL NECK

The follow-up investigations of our cases have shown that sliding of the nail, separation of the femoral head and non-union without necrosis of the head are usually caused by faulty technique

Operation with Only One X-Ray Apparatus. *Accurate reduction* of the fragments is essential to a good end-result This can be confirmed only by good roentgenograms which are repeated after each new stage of the operation so that the proper position of guide wire and nail can be seen Since, as described on p 1252, at least four anteroposterior and four lateral roentgenograms are necessary, the operation should be performed only if and when two X-ray machines are available The readjusting of a single apparatus for eight roentgenograms takes too much time and endangers the sterile operating conditions Generally more than eight roentgenograms are necessary Moreover, the X-ray tube cannot be positioned in exactly the same place for all exposures This causes different projections of the guide needles and the guide wire and thus leads to misjudgments Most of our failures occurred among our first cases, viz, in our first eight operations when we took too few roentgenograms

Faulty Position of the X-Ray Tubes Hip joint, femoral head and neck, and trochanteric region must all be clearly shown on both the A-P and the lateral roentgenograms If the femoral head is not adequately shown in the roentgenograms it is impossible to check the position of the guide wire and to choose with certainty the right length nail

If the X-ray tube for the lateral projection is placed too close to the femoral head, the head will appear far too large in projection and its outlines will be blurred because of the finite focal spot If many exposures are made with a short distance between skin and tube, X-ray burns may result as

[1] Verbandlehre

described by Jerusalem[1] The best place for the X-ray tube for the lateral projection is at the medial side of the sound knee (figs 1701, 1702)

Poor Reduction of Fragments. The operation must not be started before the roentgenograms in both projections show the fragments to be well reduced with the fracture surfaces in good contact If the distal fragment touches the proximal one along one edge only instead of over the whole fracture surface, as in figures 1847 a or 1856 c, non-union is bound to follow, usually with necrosis of the head The anteroposterior roentgenogram should never show a varus (fig 1778 e) nor a severe valgus position. This must be emphasized, since many surgeons recommend a pronounced valgus position as optimum position Some surgeons have gone so far as to expose the fracture ends and to excise enough from the cranial end of the distal fragment to make the fracture line become almost horizontal, thus creating a strong valgus position They have been led to this method by recognition of the fact that primarily impacted fractures of the femoral neck with a valgus position always develop bony union

It would be interesting if those who intentionally create strong valgus position, with or without excision, were to publish the results of follow-up examinations for at least two years after operation Probably head necrosis would frequently be found within the group in which excision had been done

If the fragments are over-pulled, as in figure 1599, traction must be decreased

The lateral view, too, must show the fragments to be well reduced, i e, without undue lateral displacement and without angulation If the dorsally-open angle of the fragments is not corrected, it may easily happen that the guide wire passes ventral to the femoral head or only catches the ventral quadrant of the head This position is the cause of later separation of the femoral head, as we have observed in one of our own cases (figs 1751—1758 a) and in many cases operated on elsewhere Moreover, cases with anterior angulation plus valgus angulation are especially prone to develop head necrosis later on

Insufficient Exposure of the Bone. Many surgeons recommend the insertion of guide wire and nail through a small incision We also have tried it in some cases but have been unable to locate the insertion hole sufficiently exactly A long enough incision should be used (approximately 15 cm long) for sufficient exposure of the bone Only then can one exactly determine the right place for the insertion hole and certainly avoid drilling in the guide wire too far ventrally or dorsally

If we use **too thin a guide wire** it will too easily bend upon hitting hard parts of the bone (fig 1743) If the nail is driven in over such a bent wire, the wire will get caught and curled up (fig 1744) It may even break and the fragments remain in the bone or joint (figs 1739—1742)

If the guide wire is much thinner than the bore of the nail a small bone splinter may become wedged between the two and jam the wire The latter is then driven in together with the nail and may also be bent (fig 1746)

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[1] Jerusalem Rontgenschadigung nach Osteosynthese des Schenkelhalses, Zentralbl f Chir 63 41, 1936





1739 July 7, 1935 1740

Figs 1739, 1740—Medial fracture of the femoral neck after nailing, the patient still on the screw-traction apparatus The fracture is well reduced In the anteroposterior view the nail is placed slightly caudal to the center of the femoral neck—a satisfactory position In the medial view the nail lies far dorsal to the center of the femoral neck but apparently without entering the joint The femoral head is hit in its center The guide wire has perforated the hip joint and has broken





1741 November 26, 1936 1742

Figs 1741, 1742—Check roentgenograms re figures 1739 and 1740, five months later The guide wire has broken a second time, viz, two weeks after operation A 10 mm long fragment of the wire lies transversely in the joint, probably in the fatty tissue of the fossa acetabuli Bony union of the fracture This 60 year old patient is now, 18 years after the operation, free from complaints though he climbs high mountains and goes hunting

All these incidents can be avoided by using sufficiently strong and hard, smoothly-polished wires They should not be too hard or brittle, either, lest they break They must glide well in the bore hole of the nail but not too



1743 September 19, 1934 1744

FIG 1743—Well-reduced fracture of the femoral neck on the screw-traction apparatus with two lead marks placed properly The guide wire lies too far caudally Because it was too thin, the wire deviated slightly when it hit the hard compact bone of the calcar femorale

FIG 1744—Check roentgenogram re figure 1743, after insertion of the nail Since the wire was bent, it was caught by the nail, driven in and bent strongly towards the cranial side The nail deviated caudally It was removed with the guide wire After insertion of a new guide wire the nail was driven in again, this time ideally The patient got up after 14 days and is symptomless 20 years later



1745 April 8, 1936 1746

FIG 1745—Well-reduced fracture with two lead marks The guide wire lies well It is not too long and is not bent in either the anteroposterior or the lateral view

FIG 1746—Check roentgenogram re figure 1745, after insertion of the nail The guide wire was driven through the pelvis and bent caudally The nail deviated cranially After retraction of the nail it appeared that its cannulated bore was slightly too large, so that a small bone splinter became wedged between the wall of the cannula and the guide wire Thus the wire was fixed firmly in the nail A new guide wire was drilled in, and the nail driven in over that wire was placed well The patient was symptomless twelve years later

loosely, lest bone splinters be caught as in figure 1746 Since 1935 we have been using guide wires 22 cm long and 2 2 mm thick

To check to see that the wire has not been driven in together with the nail, the cannulated driver is withdrawn from the wire after every two to three blows of the hammer If the wire does not protrude ever farther from the hole of the nail as the nail is driven in, it must be pulled out in time to prevent it from bending or from perforating the acetabulum

If after perforation of the cortical bone a strong resistance is felt on driving in the nail, this usually indicates a bent guide wire To confirm this, one tries to retract the wire If the wire has curled up as in figure 1744 it can only be pulled out together with the nail

If we use **too long a guide wire** the acetabulum may be penetrated, the abdominal cavity may be perforated and abdominal hollow organs or great vessels may be injured Some authors have reported such complications

If we use **too short a guide wire,** or do not drill in the wire far enough, it will catch only a small part of the femoral head Then it may happen that the femoral head is lifted on one side by the advancing nail and angulation occurs as in case 27 of Bohler and Jeschke[1] Angulation occurred in spite of the nail's being drilled into exactly the center of the femoral head in both planes Such an angulation can also occur if the guide wire is pulled out too early, i e, before the nail has been driven in deeply enough

Driving the Nail Into the Hip Joint and the Pelvic Bone. This can only occur if too long nails are used Since the X-ray film for the A-P view is, depending upon the thickness of the patient, 20—25 cm dorsal to the femoral neck, and since the distance between tube and patient is relatively very short, the projection of the femoral neck and head on the film shows them much enlarged Therefore, according to the lengths of these tube-bone and bone-film distances, 20 to 25 mm must be taken off the length of nail as measured on the film to get the real length of the nail If the guide wire just reaches the hip joint, as in figure 1722, its length on the film is measured from the surface of the femoral head to the surface of the femoral shaft Then the length of the part of the wire outside the bone is measured Thus, if the guide wire be of known length, we can judge how much of the wire lies inside the bone and how much it is enlarged Too long nails should be avoided, because necrosis of the head develops at the site where the nail has penetrated the head After insertion of the nail, roentgenograms must be made to see where the tip of the nail lies If the nail has been driven in too deeply it must be retracted with the pull-out device or nail retractor Then new roentgenograms should be made and the process if necessary repeated until the tip of the nail is 6—10 mm from the surface of the femoral head

If the tip of the nail has been driven into the acetabulum and not been retracted, movement of the hip will cause it to bore a cavity (figs 1862—1865). This allows a certain mobility at the hip joint after months If the nail is removed after one to one and a half years, i e, after bony union of the

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[1] Bohler, L and Jeschke Operative Behandlung der Schenkelhalsbruche und Schenkelhals-pseudarthrosen und ihre Ergebnisse, Vienna, Maudrich, 1938

fragments has occurred, the normal mobility of the hip joint will be recovered In the patient shown in figures 1861—1865 the nail remained in the joint for $2^{3}/_{4}$ years without causing any real harm, as it was made of good material If the nail is pulled back too early, as in case 6 of Bohler and Jeschke, angulation of the fragments and necrosis of the head may occur

Comminution of the greater trochanter can occur if the nail is inserted too far cranially and if the femoral neck is impacted too strongly Felsenreich [1] has described and published such cases A trochanteric plate should be attached to the nail (figs 1879, 1980 c) at once in these cases of comminution of greater trochanter to avoid a varus angulation Also, if the angle between the femoral shaft and the nail is less than 125°, as in figure 1778 c, a plate should be added

Questions We Should Ask Ourselves to Avoid Failures with Operative Treatment of Medial Adduction of Varus Fractures of the Femoral Neck

1 Have I excluded from operation patients in bad general condition, e g, with severe diseases of the heart, the vessels (e g, very high blood-pressure, former embolism with persisting palsy), the lungs, kidneys, bladder and prostate, or with severe diabetes or tabes?
2 Have I carried out the 15-second-breathing test?
3 Have I postponed operating until the shock had receded and the clinical examinations had been finished?
4 Have I checked all apparatus and instruments for completeness and quality (including examination with the magnet) before the operation?
5 Have I checked to see whether the guide wires and nails, driver and impactor, nail retractor and pull-out device all fit?
6 Have I tried the drilling machine?
7 Has the patient received a sedative (Trial or Heptadon, not morphine) half an hour before operation?
8 Has the patient been brought to the operating room in his bed with his thigh splint and weight traction?
9 Have I performed local anesthesia of the hip joint with the patient still in bed and under weight traction?
10 Have I protected the patient from chilling by the use of a jacket, by wrapping the legs and by keeping him covered as completely as possible?
11 Is the bed being prepared and warmed after the patient has been moved onto the traction table?
12 Have the foot slings been applied under persisting longitudinal traction after sufficient padding of both feet, especially the dorsa of the feet, with cotton-wool or cellulose?
13 Have I checked to see that the traction table is placed symmetrically, that the extension rods are pulled out sufficiently and fixed properly and that all adjustors work well?

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[1] Felsenreich Operative Behandlung der frischen medialen Schenkelhalsfraktur, Vienna, Maudrich, 1938

14 Have two 2 5 × 36 × 36 cm stitched pads been placed on the pelvic support?
15 Has a warmed cloth been put over the supports for pelvis and back?
16 Have the roentgenograms been displayed and have I once more confirmed that the fracture is well reduced?
17 Has a pelvis and thigh skeleton been placed ready for easy reference?
18 Has the traction table been adjusted to the height of the bed?
19 Has the patient been moved onto the pelvic support with his thigh splint and weight traction and with internally rotated limb?
20. Has the perineal post been inserted?
21 Have weight traction and thigh splint been removed while light manual traction is maintained on the internally rotated limb?
22 Have both limbs been fixed under light traction with foot slings to the foot plates in 40° to 60° internal rotation and with the heels 70 cm apart? Have the feet been fixed with bandages from the toes to the heels?
23 Have I seen to it that the sole of the foot is firmly against the foot plate?
24 Have I put a finger between the perineum and the perineal post to make sure that the longitudinal traction is neither too strong nor too weak?
25 Have padded cuffs been applied to the wrists and have the wrists then been fixed to a transverse frame at shoulder level?
26 Have I checked whether the limbs and the pelvis are positioned symmetrically?
27 Have both limbs been simultaneously and equally rotated inwards 40° to 60°?
28 Have I applied a knee prop in case of pain in the knee?
29 Have I located the point on the skin directly ventral to the center of the femoral head and marked that point with iodine?
30 Has the more powerful or shock-proof X-ray tube been positioned medially to the knee of the sound side? Has the central ray been focused horizontally to hit the femoral neck at right angles? Has a long cone been attached to the X-ray tube to limit stray radiation?
31. Has the other X-ray tube been positioned 55—60 cm vertically above the center of the femoral head?
32 Have both X-ray tubes been secured to the operating table?
33 Has the mediocranial corner of the wire grid been placed above the center of the femoral head and with half the wires running in the long axis of the femoral shaft?
34 Has the grid been fastened with two straps of adhesive tape covering only the ends of the wires and not the points of intersection?
35 Has the cassette with the film for the antero-posterior roentgenograms been placed in the space under the pelvic support in such a way that the femoral head and trochanteric region are included?
36 Have I attached the water level to the cassette for the lateral roentgenogram, and have I pressed that cassette in from the cranial side as deep as possible between the arch of the ribs and the iliac crest and have I then

tilted it caudally until it lies parallel with the femoral neck and exactly horizontal?

37. Was counterpressure on the sound side of the pelvis exerted when the cassette was pressed in?
38. Have I corrected a shortening and varus angulation by steadily increasing the longitudinal traction on both limbs?
39. Have I corrected a severe valgus angulation by impaction or by the procedure described on page 1266?
40. Have I corrected an anterior angulation by a simultaneous and steady increase of the internal rotation of both limbs?
41. Have I corrected a dorsal displacement of the distal fragment by manual pressure on the dorsal side and by insertion of a pad?
42. Have I checked the position of the fragments by roentgenograms until both views showed satisfactory reduction?
43. **Have I started operating only when roentgenograms in both projections showed the fragments to be well reduced? This is indispensable to a good end-result.**

The first 43 questions deal with the reduction of the femoral neck fracture They should be asked in connection with any technique of femoral neck nailing The following questions 44—80 refer to the technique described on pp 1269—1278.

44. Have I exactly located the center of the femoral neck in the A-P roentgenogram and marked it on the surface of the wet film?
45. Have I placed a transparent ruler on the A-P image of the femoral neck, the edge of the ruler passing along from the center of the femoral head at an angle of 130° to define the point of intersection between the long axis of the femoral neck and the lateral side of the femoral shaft?
46. Have I marked this point of intersection by scratching the film?
47. Have I inserted two guide needles or metal pins exactly vertically marking the center of the head and the outer side of the femoral shaft?
48. Have two observers checked the vertical direction of the guide needles?
49. Have I driven the medial guide needle or pin at least 5 mm deep into the femoral head?
50. Have I chosen the lateral guide needle long enough so that it almost pierces the skin of the posterolateral side of the thigh?
51. Have I taken A-P and lateral roentgenograms after insertion of the guide needles?
52. Have I attached the water level to the cassette for the lateral roentgenogram?
53. Have I measured with the big protractor (figs 1710—1712) on the lateral roentgenogram by how many degrees the axis of the femoral neck deviates dorsally or ventrally from the horizontal?
54. Have I removed the wire grid after defining the femoral neck axis in both planes?
55. Have I, after draping-off the operation field, applied local anesthesia by injecting 100—200 cc of a 0 5% Novocain solution down to the bone

beginning at the trochanter and proceeding caudally, the infiltration being carried out slightly ventral to the midline of the outer aspect of the thigh?

56 Have I used a long enough incision (10—15 cm)?

57 Have I sewn on the sterile towels instead of fastening them with towel clips?

58 Have I used a self-retaining retractor with its lock placed towards the knee and have I fixed it with a towel clip?

59 Have I inserted horizontally two parallel Steinmann pins to define the thickness of the bone?

60 Have I cut the notch for the guide wire ventral to the midline if the axis of the femoral neck runs in a mediodorsal direction?

61 Have I used a guide wire of proper length and diameter (2 2 mm thick and 22 cm long) and not one too thick or too weak, too short or too long?

62 Have I inserted the guide wire in the right place with the help of the indicator and the oil-level?

63 Have I checked the right position of the guide wire with roentgenograms in both planes?

64 Have I drilled the guide wire 1—2 cm deep into the acetabulum to avoid tilting of the femoral head with insertion of the nail?

65 Have I, to avoid later separation of the head, drilled the guide wire into the middle of the femoral head and not cranially or ventrally?

66 Have I repeated the insertion of the guide wire until its position was right?

67 Have I repeated check roentgenograms in both planes after insertion of each new guide wire?

68 Have I drilled the cortical bone with the 8 mm -thick cannulated trephine after insertion of the well-placed guide wire?

69 Have I cut three notches for the flanges of the nail after trephining the cortex?

70 Have I subtracted 20—25 mm from the length measured on the A-P roentgenogram to find the correct length of the nail?

71 Have I withdrawn the driver after every 2—3 strokes, when driving in the nail, to see whether the guide wire is being advanced too?

72 Have I stopped driving in the nail when an unusually strong resistance was felt, and have I taken roentgenograms to see whether the guide wire had bent?

73 Have I taken roentgenograms in both planes after insertion of the nail?

74 Have I seen to it that the tip of the nail approached to within a minimum distance of 6 mm and a maximum distance of 10 mm from the articular cortex of the femoral head?

75 Have I avoided driving the nail up to the surface of the head, as this might cause localized necrosis?

76 Have I taken new roentgenograms in both planes after driving the nail deeper or retracting it?

77 Have I impacted the femoral neck into the head with the impactor if there was a gap between the fragments and have I omitted impaction in all other cases?
78 Have I taken new A-P and lateral roentgenograms after impaction of the fragments?
79 Have I excised the soft tissues damaged at operation?
80 Have I compressed the sutured wound strongly to avoid hematoma?
81 Have I applied a compression bandage as a spica coxa trochanterica and not a spica coxa inguinalis?
82 Have I padded the compression bandage in such a way that the bandage itself nowhere touched the skin?
83 Have I inscribed the bandage properly?
84 Have I placed the limb on a pillow instead of a Braun splint, as peroneal palsy may develop on the latter?
85 Have I raised the foot of the bed 50 cm for 4—5 days?
86 Have I told the patient to move actively his toes, ankle and subtalar joints through their full range from the first day after operation?
87 Have I checked on every rounds to see that these exercises were being carried out?
88 Has the patient started to exercise his sound leg on the "mountain climber" apparatus from the eighth day on if no discomfort is caused thereby?
89 Has the patient exercised the injured leg on the knee-flexion apparatus from the tenth day on? Have the exercises been started at five minutes twice daily and have they been extended by five minutes per session daily up to 45 minutes twice a day provided they have caused no pain or other disturbance?
90 Have I taken A-P roentgenograms in external and internal rotation and a lateral roentgenogram before the patient was allowed up?
91 Has the patient been allowed up in a case of uneventful healing 14 days after operation, and has an Unna's paste dressing been applied to the foot and lower leg and an elastic bandage about the knee joint before the patient started walking with two quadripod canes, the walking to be allowed only if it was painless?
92 *Have massage and passive movements been avoided?*
93 Have I taken the three roentgenograms one week after the patient got up and again at the end of the treatment and have I repeated them every three months in the beginning and every six months later on?
94 Have I omitted removing the nail in non-union and necrosis of the head, since the condition always then deteriorates unless an arthrodesis or arthroplasty is performed?
95 Have I excised the femoral head immediately and replaced it by an endoprosthesis if closed reduction was not possible? (This was necessary in only two out of our 800 cases)
96 Have I omitted removing the femoral head if reduction was possible with continuous traction?







1751 1753 August 19, 1937 1752







1754 1755 August 25, 1937 1756

FIGS 1751—1753 —Medial adduction or varus fracture of the femoral neck in a 75 year old female who slipped on a wet floor Marked shortening, lateral displacement and angulation Figure 1752 shows that the fracture line does not run in an even plane across the femoral neck the cortical bone of the neck is fractured cranially and caudally close to the cartilaginous margin of the head, while the cancellous bone of the neck has remained connected to the head This is still more clearly shown in figure 1754

FIG 1754 —Check roentgenogram re figures 1751 and 1752, after satisfactory reduction in the screw-traction apparatus Jeschke's wire grid has been applied and the guide needles inserted

FIG 1755 —Check roentgenogram re figures 1751—1753, after insertion of the nail The gap between the fragments has disappeared The fracture is very well reduced The nail lies in the center of the femoral neck and head It is not driven in deep enough, since its tip is separated from the articular cortex of the head by about 13 mm rather than by 6 to 10 mm as should be the case

FIG 1756 —Comparison picture re figure 1755, lateral view The nail does not lie in the center of the head but rather too far ventrally

EARLY AND LATE COMPLICATIONS FOLLOWING MEDIAL FRACTURES OF THE FEMORAL NECK

Complications may develop at once or after weeks, months, or even years Therefore we differentiate early and late complications

Late Complications	*Early Complications*
1 Necrosis of the femoral head,	1 Death,
2 Non-union of the femoral neck,	2 Separation of the femoral neck,
3 Arthrotic changes of the hip joint, and	3 Moving of the nail, and
4. Fracture of the nail	4 Pain and limited motion

Origin, Prevention and Treatment of the Early Complications Following Medial Fractures of the Femoral Neck

Deaths

Fractures of the femoral neck usually occur in old people Patients suffering from severe diseases of the heart and circulatory system, or from other diseases, e g, of the lungs or urogenital tract, often die from pneumonia, decubitus ulcers or ascending urinary infection after sustaining fracture of the femoral neck These complications are prevented best if the patients are protected from chilling, if local anesthesia is applied at once, if these patients are kept pain-free and mobile in properly applied continuous traction and then nailed in time in the absence of contraindication Mortality in this



1757 1758 October 27, 1937 1758 a

FIGS 1757—1758 a—Check roentgenograms re figures 1755 and 1756, two months later The patient walked well at first, but then pain suddenly developed and the roentgenogram showed that the nail had come out of the femoral head Redisplacement of the fragments as before reduction Separation would not have occurred if the nail had been placed slightly caudal and dorsal to the center of the femoral neck and head and had been driven in deep enough After renailing, bony union occurred but caput necrosis developed later

operation is relatively low if the cases are selected properly and the operation performed under local anesthesia

Separation of the Femoral Neck

Origin

(a) Poor position of the nail, e g, too far cranially or ventrally, or too far caudally or dorsally, or not deep enough (figs 1755—1758 a) or too flat (fig 1778 c),
(b) Sliding of the nail (figs 1774—1777, 1778 d), or
(c) Fracture of the nail (fig 1778 e)

Prevention of Separation of the Femoral Head Separation can be prevented if the nail is never placed ventrally or cranially to the center, if the distance between the tip of the nail and the surface of the head amounts to not more than 10 mm, and if the nail is placed at an angle of not less than 125°

Treatment of separation of the femoral head is not very hopeful, since necrosis of the femoral head develops as a rule if a new nail is inserted in a

different position Therefore, the best treatment in a case with severe complaints is arthrodesis (figs 1565 e, 1855) or arthroplasty (figs 1565 b, c, 1733)

Central Advance of the Three-Flanged Nail

Origin If a nail appears to advance centrally towards the acetabulum it is a sure sign of total necrosis of the head In reality the nail remains unchanged, *if anchored sufficiently* in the lateral fragment, while the head, moving

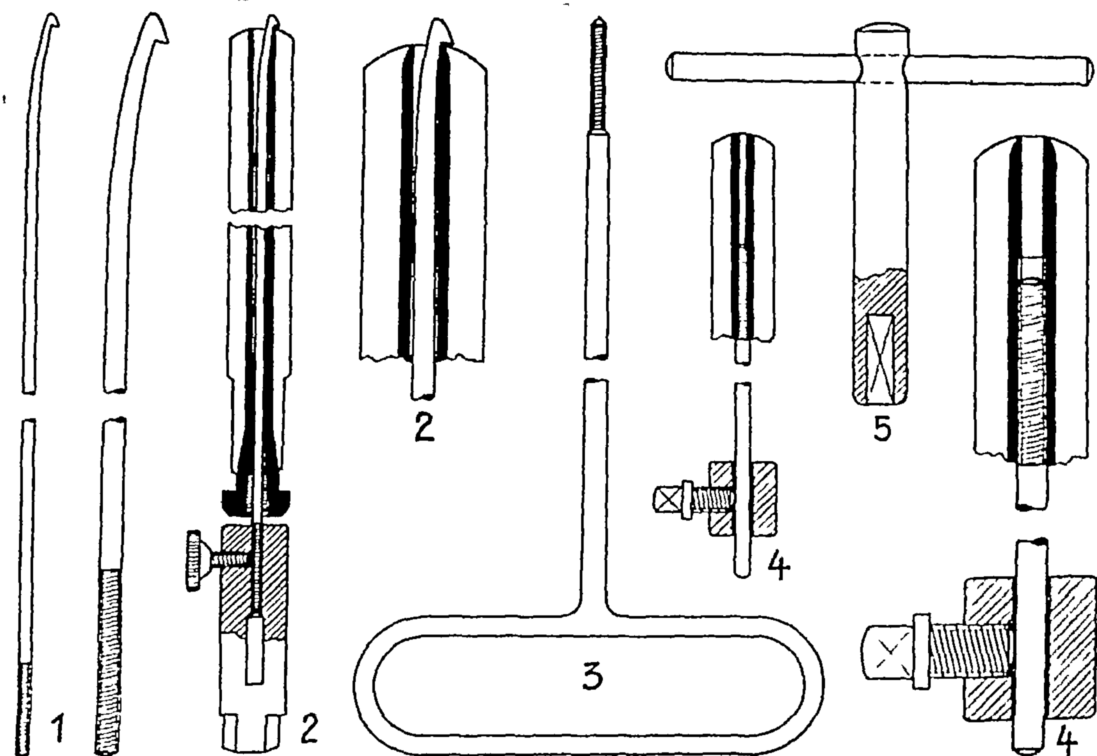


FIG 1759—Instruments used to extract broken three-flanged nails (1) Curved hook with thread (half the normal size and full scale), (2) Broken three-flanged nail with inserted hook screwed to a pull-out device, (3) One of the three thread-cutting instruments, (4) Broken three-flanged nail with thread cut and pull-out pin inserted A strong set-screw (fig 1679) is applied to the pin at its lower end To this set-screw the nail extractor shown in figure 1685 is attached, and (5) End-wrench for tightening the (fig 1679) set-screw

laterocaudally because of absorption of the medial part of the neck, is pierced by the nail (figs 1770—1773, 1779 a, b, 1851, 1856 d, e)

Prevention of Central Advance of the Nail This cannot be prevented, as it is the consequence of a total head necrosis caused by a primary circulatory disturbance

Treatment of Central Advance of the Nail The nail may be removed and replaced by a shorter one But this is no permanent cure because the necrosis will go on If the complaints become severe, arthrodesis (figs 1565 e, 1855) or arthroplasty (figs 1565 b, c, 1733) may be performed





1760 July 5, 1937 1761





1762 July 8, 1937 1763

Figs 1760, 1761—Non-union of femoral neck fracture sustained by a 51 year old man when skating five and a half months previously Treated elsewhere with femoral wire traction of 3–4 Kg for six weeks Then traction through a plaster bandage above the knee He started walking then with crutches, and when these roentgenograms were made walked with severe external rotation of the limb with the help of two sticks Pain on walking The anteroposterior roentgenogram shows a non-union, the bone ends are not yet sclerosed Severe displacement of the fragments, severe external rotation, and cranialward displacement of the trochanter The lateral view shows marked angulation with a dorsally open angle of 65^0 Lateral displacement by two-thirds of the bone's width The femoral neck touches the fracture surface of the head with only its posterior edge Considerable decalcification of all bones The head is not dense, indicating good circulation in the head

Figs 1762, 1763—Check roentgenograms re figures 1760 and 1761, after operation The fracture was reduced within three days in pin traction with 12 Kg and with marked internal rotation of the limb Satisfactory position of the fragments and the nail Started walking with the help of two sticks 14 days later, walked well and without pain with the help of one stick 18 days after operation

Lateral Retrogression of the Three-Flanged Nail

Origin It develops if an osteosynthesis is not stable, e g, a bone wedge has broken out of the calcar femorale (figs 1774—1777, 1778 d), or if the nail is not fixed by steps cut into the lamellae (figs 1680, 1724) or by an





1764 December 1, 1937 1765





1766 December 3, 1937 1767

Figs 1764, 1765—Check roentgenograms re figures 1760 and 1761, five months later He had been able to walk without a stick, when suddenly one week before these films were made pain set in and he had to use a stick again The roentgenograms show a fracture through the middle of the nail with varus and anterior angulation Good callus formation, the fracture gap almost filled, fair general calcium content

Figs 1766, 1767—Check re figures 1764 and 1765, after 48 hours of longitudinal traction with 12 Kg through a tibial tubercle pin Roentgenogram made with the patient in the screw-traction apparatus and with Jeschke's wire grid in place Angulation has disappeared in both views

additional nail or a screw Because of insufficient stability, weight-bearing causes slight movement between head and neck This slowly drives the nail out In the case of a total head necrosis the nail may also move laterally if it is not fixed in the lateral fragment by steps cut into the flanges, or if the head of the nail is not anchored by an additional nail or screw or by a supplementary plate and screws (figs 1879, 1980 c)

Treatment of Lateral Retrogression of the Nail If the position of the fragments has remained satisfactory in spite of the moving nail, the nail is pulled out and a new sufficiently long nail with a screw-thread is driven in and fixed to the femur with a plate (figs 1879, 1980) If, however, a varus



1768, December 3, 1937



1768 a, December 16, 1937



1769, December 16, 1937



1769 a, March 20, 1938

FIG 1768—Check roentgenogram re figure 1766, after insertion of a wire with a split button at its tip The distal fragment of the nail has been extracted 1 cm The proximal fragment was caught with a thread-cutting instrument and pulled out

FIGS 1768 a, 1769—Roentgenograms with the limb in internal and external rotation after insertion of the new nail To anchor the nail laterally a 3 cm long and 2 cm wide bone graft was driven in under the head of the nail The place of excision of the graft is clearly visible in the shaft of the femur

FIG 1769 a—Check roentgenogram re figures 1768 a und 1769, three months later Bony union The implanted bone graft is hardly visible Hip joint freely mobile in all directions Patient walks without pain, without cane

angulation has formed as shown in figs 1776, 1777 and 1778 c & d, this angulation must first be corrected Then the new nail is driven in and fixed with plate and screws

Fracture of the Nail

Fractures of the three-flanged nail occur either if it is placed too flat (figure 1778 e), or if it corrodes in spite of good position (figures 1764, 1765) or if it is simply too weak. Felsenreich has collected from the literature 400 cases of nailing with 13 fractures of the nail. Up to the end of 1937 we had observed one fracture of the nail amongst 131 personal cases and one more fracture in a farmer who did hard physical work just a few weeks after operation. In this patient a second nail broke, too. Only the third nail held when a bone graft was added. The fracture of the three-flanged nail can as a rule be prevented if only amagnetic, sturdy nails with sufficiently broad lamellae are used, and if they are not placed too flat.

Removal of Fractured Three-Flanged Nails. If the proper instruments are at hand the removal of even the medial fragment is possible if displacement is not too great and if not too much time has elapsed.

Instruments for Removal of Fractured Three-Flanged Nails. At present we use a curved hook (fig. 1759/1). Its peripheral end carries a screw-thread. To this the cannulated and threaded pull-out device is screwed and fixed with a set-screw in addition (fig. 1759/2). After very accurate reduction (figs. 1766, 1767) one tests with a guide wire whether the cannula of the nail is passable, if not, it is drilled out. Then with light strokes of a hammer the hook attached to the pull-out device is driven beyond the tip of the fractured nail, which it will then catch thanks to its elasticity. Both fragments can then be removed with the pull-out hook (fig. 1679). This has usually been possible without great difficulty.

If no hook and no proper pull-out device are available, or if the former breaks, a screw-thread can be cut into the bore of the central fragment with one of three thread-cutting instruments of graduated sizes (fig. 1759/3). Then a guide wire with an adequate thread (fig. 1759/4) can be screwed in. The fractured peripheral part of the three-flanged nail, which has previously been removed, is put over the wire or driven in. The strong set-screw is pushed over the guide wire up to the head of the nail and fixed with the spanner (fig. 1759/5). The nail retractor (fig. 1685) is then attached to the head of the nail and thus both fragments of the nail can be pulled out.

If the peripheral fragment of the nail is not reinserted, or if the set-screw is not brought close to the head of the nail as shown in figure 1768, the fractured flanges of the central fragment will get caught in the bone and can be removed only by chiseling off the cortical bone. This would weaken the bone. After removal of the fractured nail an ordinary guide wire is inserted and its length is defined by two roentgenograms. Then a new nail is driven in over the wire and fixed with plate and screws (figs. 1879, 1980 c). Werner Keil[1] has also devised an instrument for removal of fractured femoral neck nails.

Here is a report showing how, after different technical trials, we removed our first fractured three-flanged nail from a femoral neck.

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[1] Keil, Werner: Monatsschr. f. Unfallheilk., 310–314, 1949.

A 51 year old man fell when skating in the middle of January 1937 and broke his left femoral neck, 5$^1/_2$ months after the injury he was admitted with non-union and severe displacement of the fragments (figs 1760, 1761) He walked with the help of two sticks Walking was limping and painful He was reduced in pin traction and then operated on (figs 1762, 1763) 14 days later he walked without pain with the help of two sticks, 18 days after operation he walked with one stick, three months after operation he could walk without a stick Slight pain on walking set in five months after operation The patient had roentgenograms made and sent them to us They showed a fracture of the nail and angulation of the fragments (figs 1764, 1765) He was admitted, and the angulation of the three-flanged nail was corrected with tibial tubercle pin traction of 12 Kg within 48 hours (figs 1766, 1767)

The patient was then put on the screw-traction apparatus as for ordinary femoral neck nailing (see page 1258) The femur was exposed with an incision through the old scar The vicinity of the head of the nail showed no reaction and no brown discoloration Serous fluid dripped out of the bore of the nail A 1 6 mm thick wire was introduced into the nail It was not difficult to pass the wire beyond the site of fracture of the nail 2 cm from the tip of the nail the wire stopped It was therefore pushed on with the electric drill Anteroposterior and lateral roentgenograms showed ideal alignment of the fragments of the nail (figs 1766, 1767) The thin wire was removed and a 2 2 mm thick wire was inserted with a split, thickened end Its two halves sprang apart by their elasticity We hoped that the two ends would catch the nail when pushed beyond the end of the cannula and then pulled back After insertion of this wire the cortical bone of the outer aspect of the femur was removed from round the nail with a chisel in order to set the lamellae free The nail was pulled back 1 cm (fig 1768) The wire was equipped with a strong set-screw (fig 1759/4) to which the nail extractor was attached But the wire came back without bringing with it the medial fragment of the nail Now the lateral fragment of the nail was pulled out completely A thread-cutting instrument (fig 1759/3) of proper size was introduced into the medial fragment The entrance to the bore of the nail was found only after some search A screw thread of eight turns was drilled A preliminary test had shown that five turns were necessary to hold 100 Kg Now the nail came out with the drill When it had been extracted up to the cortex, the cranial flange came out, whereas the two caudal ones got caught in the cortical bone They were therefore chiseled out During this the thread drill broke Only after great difficulty when the flanges could be clamped with forceps and needle holder could the nail be removed

Then a guide wire was inserted into the old drill hole of the bone Roentgenograms in both views showed satisfactory position A new nail was driven in as usual When the roentgenograms showed satisfactory position of the nail and the fragments in both planes, a bone graft 3 cm long and 2 cm wide was taken from the outer aspect of the femur and driven in beside the nail where the cortical bone had been excised The nail thus had a firm hold (figs 1768 a—1769 n) Nowadays we would attach a plate to such a nail (fig 1879, 1980 c)

Examination of the nail showed two areas of corrosion close to each other in the cranial lamella The nail was weakened by this so much that it broke on weight-bearing

To my knowledge this is the first case of a successful removal of a fractured nail from the femoral neck

Fourteen days after operation the patient was allowed up, two days later he walked well with one stick Three months later he could walk without pain and without a stick

If some time has elapsed since the fracture of the three-flanged nail, and if considerable displacement of the fragments has occurred, it will not be possible to reduce the fracture and to remove the central fragment of the nail by the above mentioned method If, in such a case, severe complaints develop because of head necrosis and arthrotic changes, the femoral head with the fractured medial fragment of the nail should be removed Then an arthroplasty (figs 1565 c, 1733) or an arthrodesis (figs 1565 e, 1859 a) can be performed

Summary of the Early Complications Following Femoral Neck Fractures. The above notes show that separation of the femoral head, gliding out of the





1770 November 16, 1935 1771





1772 July 27, 1937 1773

FIGS 1770, 1771 —Fracture of the femoral neck in a 46 year old cooper, 5 months after operation (case 24 of Bohler and Jeschke) Good position of the nail in both views, but increased relative density of head Resumed full work as a cooper three months after operation

FIGS 1772, 1773 —Check roentgenograms re figures 1770 and 1771, two years after operation One year after operation, pain had set in at the hip Roentgenogram then showed that the nail had shifted almost to the surface of the femoral neck because of absorption of the head fragment Now the nail has penetrated the hip joint because of further absorption of the femoral head The lateral view shows a sequestrum ventral to the tip of the nail The head is dense, i e, dead This penetration of the nail through the femoral head is a definite sign of total necrosis of the head

nail and fracture of the nail can generally be prevented if, after satisfactory reduction of the fragments, the nailing is performed by a correct technique and if amagnetic, sufficiently hard and strong nails with steps cut into the flanges are used The advance of the nail toward the hip joint cannot be prevented because it is a consequence of a total necrosis of the femoral head resulting from primary vascular damage





1774 December 16, 1935 1775





1776, January 7, 1936 1777, April 27, 1936

Figs 1774, 1775—Medial fracture of the femoral neck with a bone wedge broken off medially Sustained by a 71 year old female who fell on the street These are roentgenograms made at operation (case 28 of Bohler and Jeschke) Good position of the fragments The nail lies in very good position in the anteroposterior view but too far dorsally in the lateral view

Fig 1776—Check roentgenogram re figure 1774, after 23 days The patient was allowed up 14 days after operation and could walk well with the help of two canes There is a slight coxa vara, because the femoral head lacks the support of the broken caudal cortical wedge and because the nail lies too far dorsally In such cases with a bone wedge broken from the calcar femorale, a pertrochanteric plate should be fixed to the nail as shown in figures 1879 and 1980c

Fig 1777—Check roentgenogram re figure 1774, four months later Coxa vara has increased The head's settling caudally has caused the nail to be driven laterally The nail was removed and replaced by a new one This second nail later penetrated into the hip joint because a total necrosis of the femoral head had developed Such gliding out of the nail occurs only if the osteosynthesis is not stable

Origin, Prevention and Treatment of Late Complications Following Medial Fractures of the Femoral Neck. Necrosis of the Femoral Head

Until 1902, non-union of the femoral neck was accepted as an unavoidable consequence of every medial fracture of the femoral neck, whereas necrosis of the femoral head was not discussed Schmorl[1] was the first to report on this

[1] Schmorl Munchen med Wchnschr *71* 1381, 1924

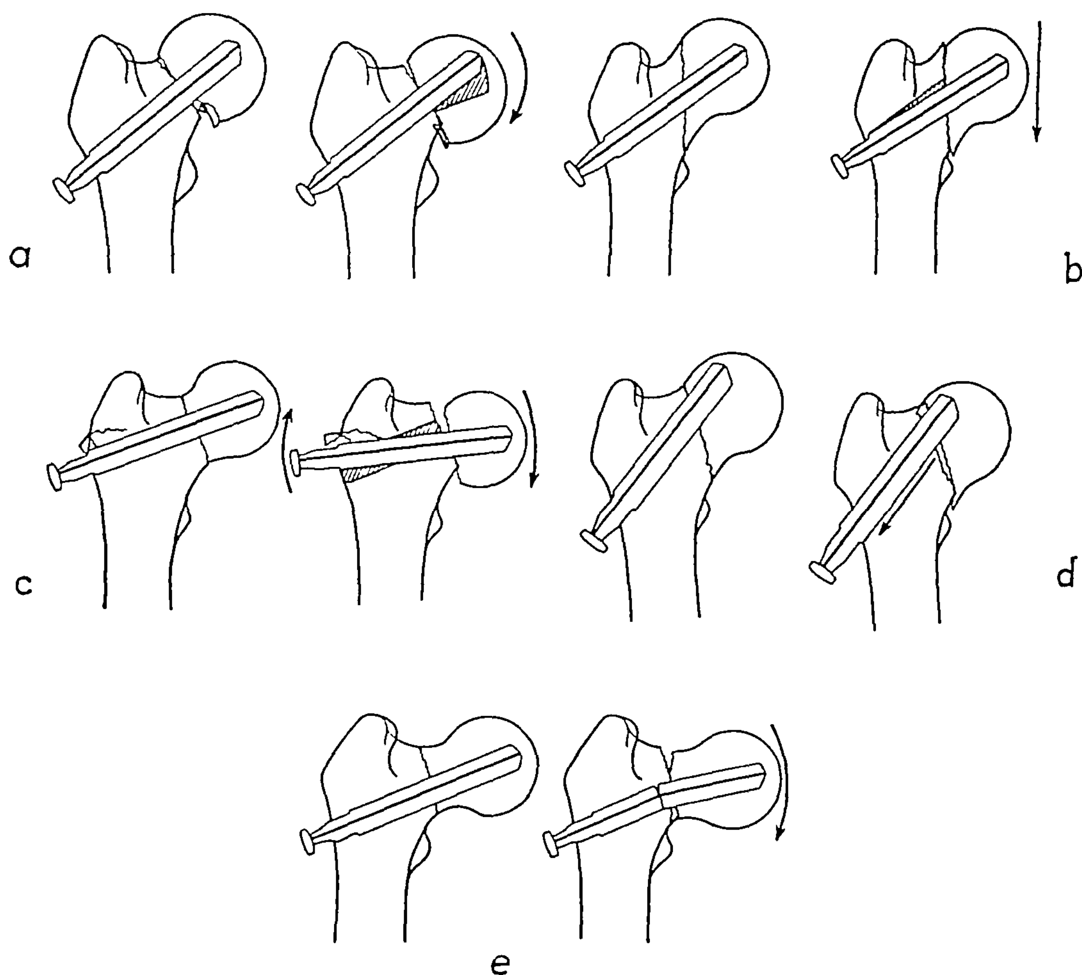


Fig 1778—Examples of unstable osteosynthesis of the femoral neck after a diagram of Ender's[1] (a) The head sinks into varus position leaving a relatively radiolucent zone caudal to the proximal part of the nail in a nailed femoral neck fracture with a bone wedge broken out of the calcar femorale This angulation can be prevented if the shortening is fully corrected before the operation and if a slight valgus is achieved (b) Cranial displacement of the distal fragment leaving a relatively radiolucent zone in the femoral neck cranial to the nail in a nailed femoral neck fracture, Pauwels' group III This displacement can be prevented by attaching a plate as in figures 1879 and 1980c (c) The head sinks into varus because the nail lies at an angle of 100° instead of 130° with the femoral shaft and because the cortical bone at the outer side of the femur has been comminuted The sinking of the head can be prevented in such cases if a plate is attached to the nail as in figures 1879 and 1980c (d) Gliding out of a nail which has been placed too far cranially and therefore grips too little of the head This leads to separation of the fragments (e) Fracture of the nail The nail has been driven in without correction of the varus, the angle being 112° instead of 125°—135° This leads to constant shearing stress on the nail

complication on the basis of thorough pathologic investigations Arthrotic changes had often been reported Reviewing the roentgenograms concerned, one finds many cases of necrosis with depression of the femoral head Total or partial necrosis occurs in some fractures of the femoral neck no matter whether they are treated conservatively or operatively or whether they are

[1] Ender, J Arch orthop u Unfall-Chir *46* 237–253, 1952

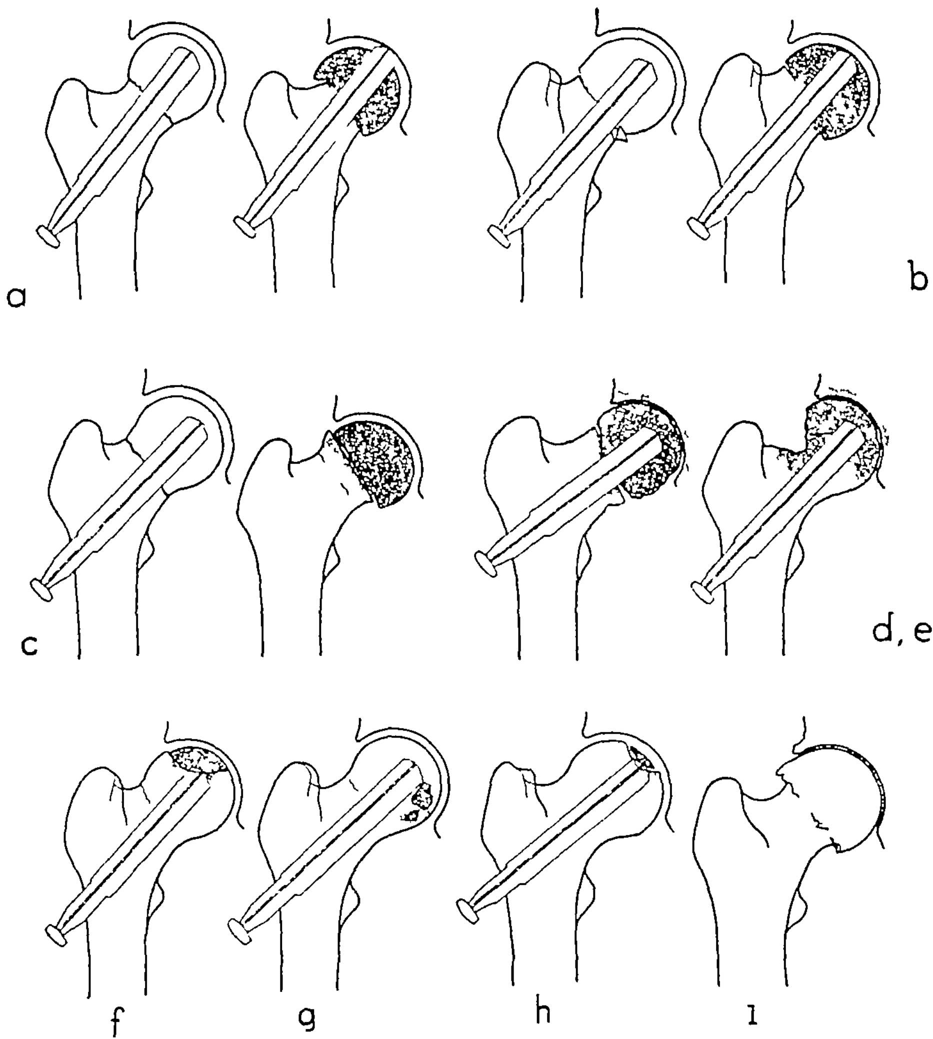
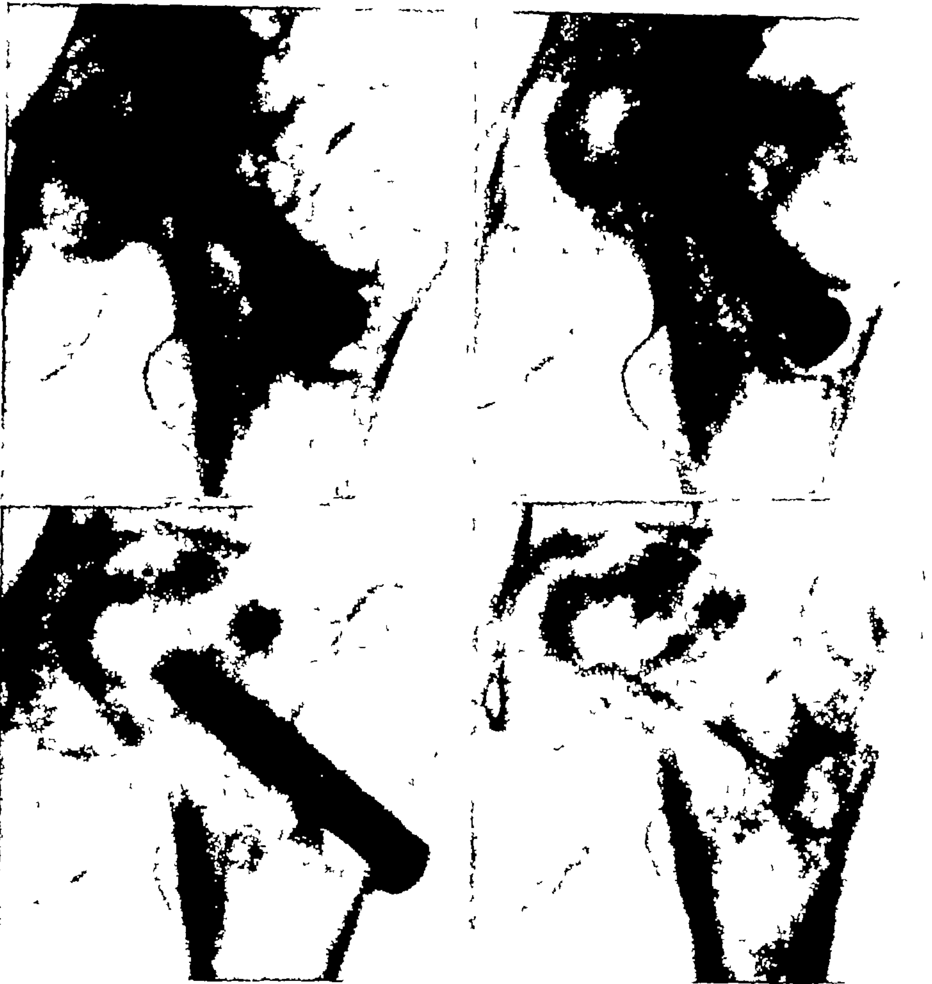


Fig 1779—Examples of necrosis of the femoral head, after a diagram of Ender's (see page 1306) (a) Avascular total necrosis of the head in spite of good reduction of the fragments and good position of the nail The nail has perforated the head and has entered the hip joint because of absorption of the neck part of the head fragment (b) Avascular total necrosis of the head in a femoral neck fracture nailed in slight varus and with a bone wedge broken out of the calcar femorale The coxa vara has increased and the nail has moved towards the hip joint "space" (articular cartilage) (c) Pseudarthrosis of the femoral neck in avascular total head necrosis after removal of the nail Revived zone medial to the former fracture line (see figures 1818—1820) (d) Septic total necrosis with sequestration of the whole head (e) Septic partial necrosis with destruction of the head and narrowing of the joint "space" owing to a low-grade infection Bony union of the fracture (f) Avascular partial necrosis, type I, with depression of the head opposite the acetabular roof at the place of the most stress on weight bearing (g) Avascular partial necrosis, type II, with cysts and sequestra in a region of little functional importance (h) Small depression of the head due to a rust granuloma at the tip of the nail Similar circumscribed necrosis also develops if a nail is driven through the surface of the head and then later retracted to the correct place (i) Arthrotic changes in the hip joint with marginal exostoses and narrowing of the articular cartilage after removal of the nail

not treated at all Cysts and small, dense, necrotic foci develop (figs 1738, 1820) as well as all grades of necrosis including complete necrosis and absorption of the head (figs 1647—1677, 1772, 1779—1801, 1834—1837, 1849 through 1856)

1780, September 4, 1935 1781, May 7, 1936



1782, October 4, 1937 1783, December 8, 1939

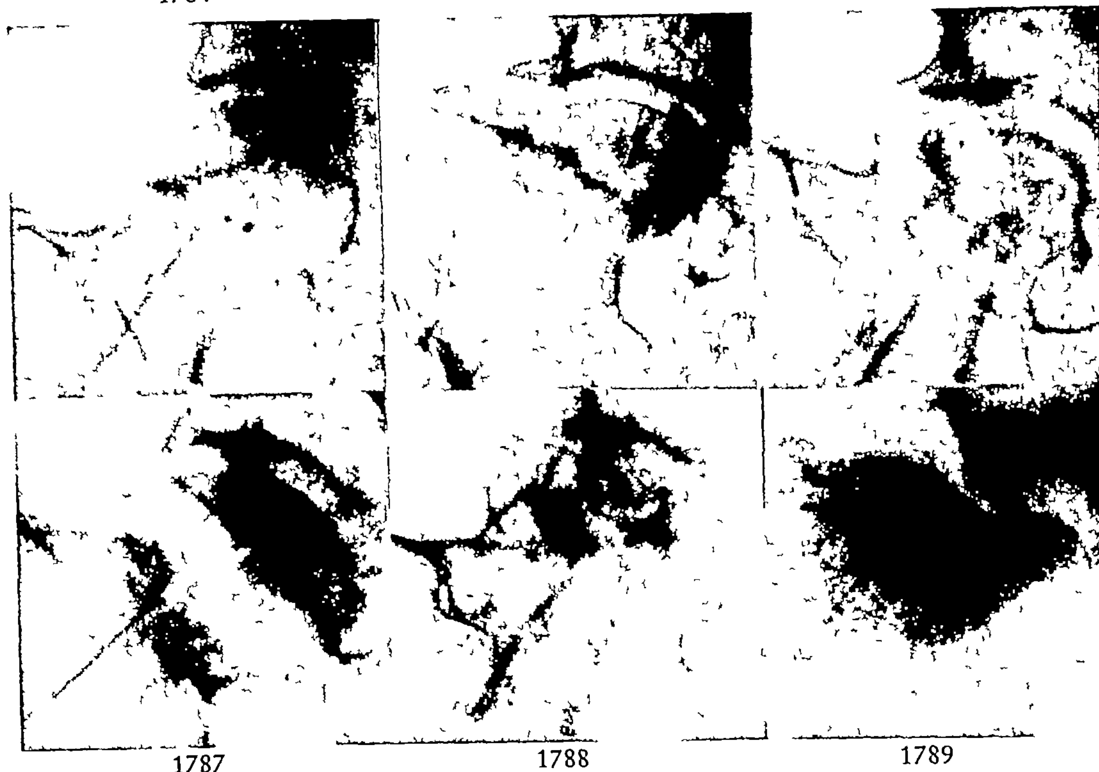
FIG 1780—Fracture of the femoral neck operated on one and a half years before i films were made and fixed with a martensite, magnetic three-flanged nail The fem head is flattened because a 25 mm broad rust granuloma has formed round the tip of nail Round the head of the nail a 20 mm broad cavity has developed because of rust articular cartilage thickness (joint "space") is well preserved Pain on walking Mobility ii directions severely limited

FIG 1781—Check roentgenogram re figure 1780, eight months later Small drepression in femoral head The rust granulomas round the tip and the head of the nail have incre in size

FIG 1782—Check roentgenogram re figure 1780, two years later Limb here in inte rotation Flexion 180°—160° Rotation and abduction of only a few degrees Severe pain standing and walking

FIG 1783—Check roentgenogram two years after removal of the nail and six years a original operation The cavity in the femoral head is beginning to fill with bone Pai felt only when walking long distances Patient can walk well indoors, does not need a c Flexion of hip joint 180°—140° Abduction limited by half, rotation limited by two-thi

Causes of Total and Partial Necrosis of the Femoral Head (1) Rupture vessels at the time of accident, (2) Inadequate reduction, (3) Too force reduction, (4) Distraction through continuous traction; (5) Operative redu



Different forms of necrosis of the femoral head, after Bohler and Ender [1]

FIG 1784 —Partial necrosis of the head following a medial fracture of the femoral neck nailed four years before this roentgenogram (58 year old female) Depression of the head opposite the acetabular roof with sclerosed wall So far no arthrotic marginal exostosis Clinically occasional pain Patient walks with slight limp Hip flexion 160^0—90^0 Abduction and rotation limited by one third to one half

FIG 1785 —Total necrosis with wedge-shaped "sequestrum" and severe arthrotic changes following a medial fracture of the femoral neck nailed $4^1/_2$ years earlier (59 year old female) Wedge-shaped depression opposite the acetabular roof surrounded by a revived zone 1 cm broad Marginal exostoses 5 mm wide at the head and 15 mm wide at the acetabular roof Clinically pain, severe limp Adduction contracture, hip flexion 155^0—120^0, abduction and rotation nil In this case an arthrodesis or arthroplasty is indicated

FIG 1786 —Total necrosis revived to a large extent after a medial fracture of the femoral neck nailed three years earlier (55 year old female) Head flattened, showing cysts and dense foci, mostly revived Marginal exostosis 20 mm wide from the acetabular roof, joint "space" narrowed Clinically pain, patient can walk only short distances Hip joint flexion 170^0—90^0 Abduction and rotation limited by two-thirds

FIG 1787 —Total necrosis with "shifting non-union" after a medial fracture of the femoral neck nailed two years earlier (73 year old female) Site of non-union medial to the former fracture and a revived zone 15 mm broad Head and revived zone dense, joint "space" of normal width Figures 1856 a–f show the development of this "shifting non-union" Eleven years later the trochanter lies high up, the head is almost completely absorbed and rebuilt, the joint "space" has disappeared as in figure 1666

FIG 1788 —Total necrosis with revival and slight arthrotic changes after a medial fracture of the femoral neck nailed 14 years ago in a 28 year old female shop assistant Head flattened, completely revived, joint "space" somewhat narrowed, marginal exostoses from head and acetabulum Clinically rare complaints Walks with a slight limp Shortening of 2 cm, hip flexion 180^0—90^0, abduction 20^0, only minimal rotation

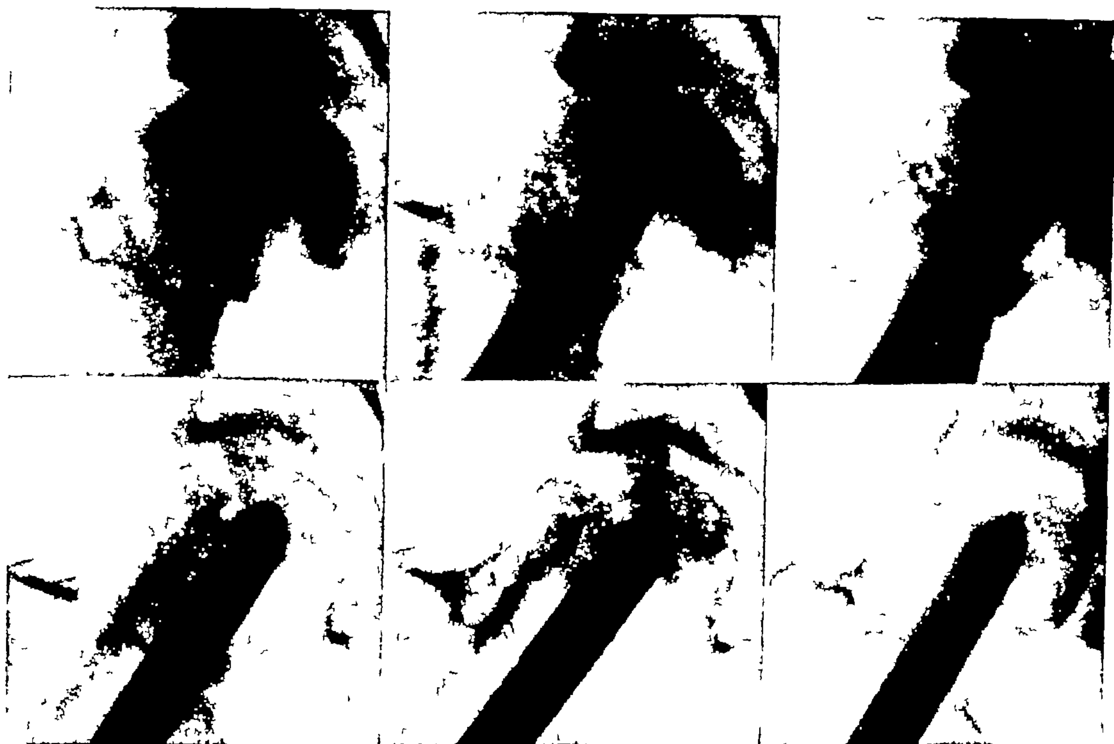
FIG 1789 —Total necrosis with absorption of the head after a medial fracture of the femoral neck nailed seven years earlier in a 70 year old female Femoral head absorbed What is left of the femoral neck is propped against the acetabular roof She can walk only with the help of a cane Hip joint flexion 180^0—80^0, abduction limited by half, rotation is almost nil Compare with figures 1658 and 1673

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[1] Bohler, L and Ender, J Huftkopfnekrosen nach Schenkelhalsnagelung, ihre Haufigkeit und Versuche der Verhutung Wiederher Chir Traum 1 122, 1953

tion with exposure of the fragments, (6) Driving in the nail too deeply, into the hip joint or into the fovea centralis, (7) Use of two nails; (The preceding three measures in themselves destroy still more vessels), (8) Excessive impaction of the fragments, (9) Destruction of the bone by rust-granulomata; (10) Use of screws whose thread catches not only the central but also the distal fragment, (11) Interposition of folds of the capsule with narrowing, occlusion or thrombosis of vessels in untreated fractures, (12) Allegedly premature

1790, February 25, 1948 — 1791, June 7, 1948 — 1792, January 9, 1949



1793, February 15, 1949 — 1794, January 30, 1950 — 1795, November 16, 1951

Development of a partial necrosis of the head in spite of implantation of an autogenous tibial bone graft, after Bohler and Ender (see page 1371, footnote)

FIG 1790—Four week old medial fracture of the femoral neck in a 48 year old unskilled worker Accident on January 26, 1948, operation on March 1, 1949

FIG 1791—The fragments are well reduced, correct position of the nail Superimposed on the cranial quarter of the head shadow is 8 × 8 mm os acetabuli

FIG 1792—Callus has bridged the fracture One mm "step" in the surface of the head opposite the cranial acetabular margin, another "step" is visible medial to the tip of the nail The part of the head lying between these two steps is limited caudally by a thin zone of sclerosis

FIG 1793—Six weeks after implantation of a tibial graft The surface of the head presents a normal contour because the small depression has been lifted by the graft The sclerosed zone has become more pronounced

FIG 1794—One year after the bone grafting Clear-cut steps have formed although most of the body weight was borne on crutches

FIG 1795—There is now collapse of a part of head corresponding to that originally seen to have been affected

weight-bearing All the factors so far enumerated cause aseptic necrosis, but there is also (13) septic necrosis after infection of the wound

1 The most frequent and most important cause of circulatory disturbance of the femoral head is the rupture of vessels at the time of the fracture of the bone by simultaneous rupture of the capsule and the periosteal covering containing the vessels The other causes are far less important and by themselves can only rarely lead to total necrosis Necrosis is the more

1796 a and b, April 17, 1947



1796 c and d, January 22, 1951

FIGS 1796 a—d —Example of revival of a femoral head after almost complete necrosis (Ender [1])

FIGS 1796 a, b —Necrosis of the femoral head in a 28 year old salesman, fracture nailed one year earlier Two months before these films were made the nail was removed because of severe pain These ckeck roentgenograms show bony union The anteroposterior view, however, shows a depression of the head cranial to the track of the nail The lateral view shows a relatively radiolucent zone with revived parts of the head laterally and dense, partly necrotic parts medially Treatment weight-bearing splint for three years

FIGS 1796 c, d —One year after removal of the weight-bearing splint, five years after the injury and the nailing The head is flattened but it has not collapsed any further The lateral view clearly shows the revived medial part of the head The joint "space" is narrowed cranially Subluxation of the head Clinically walks without perceptible limp, feels no pain Shortening of 1 cm Active motion of the hip joint flexion and extension free, abduction and rotation only slightly limited Other joints freely mobile Slight wasting of muscles Three years later, no further changes

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[1] Ender, J Arch Orthop u Unfall-Chir *46* 237—153, 1952

frequent and extensive, the greater the displacement of the fragments and the nearer the fracture line runs to the femoral head, since the main vessels enter the head cranially (fig 1564 g, h) Fractures with severe displacement are followed by necrosis in 40 per cent of the cases, fractures with slight displacement are followed by necrosis in only 10 per cent

2 If the fragments are not well reduced and the fracture surfaces are not well apposed, if they have no contact at all (fig 1731) or have contact only along one edge (fig 1856 c), new blood vessels cannot grow from the peripheral fragment into the central fragment Varus position, too, often results in partial necrosis of the head Amongst eight patients nailed in varus position, six developed a partial necrosis with some collapse of the head Varus position plus anterior angulation means a special danger Accurate reduction of the fragments is the best prophylactic against necrosis

3 Forceful reduction under general anesthesia, especially excessive internal rotation, may rupture further vessels at the dorsal or cranial side of the femoral neck Among 20 patients manipulated under a general anesthetic without achievement of a satisfactory position of the fragments, 13 developed partial necrosis

4 The use of too-heavy weights during the continuous traction causes distraction of the fragments (fig 1599) If excessive traction is maintained through a considerable period, mechanical stretching and spasm of vessels cause narrowing of the vessels and thus impaired circulation

5 Exposure of the hip joint for open reduction may injure further vessels (figs 1847—1853)

6 If the nail is driven into the surface of the femoral head or into the fovea centralis, further vessels of the head (fig. 1564 g, h) may be severed Immediate retraction of the nail cannot undo the damage done

7 Two nails sever more vessels than does one, especially when they are driven in deeply

8 Excessive impaction may injure the bone or its cartilaginous cover

9 As long as we used magnetic nails, rust-granulomas followed by secondary collapse of the femoral head often occurred (figs 1780—1783)

10 To prevent non-union, many surgeons use screws instead of the three-flanged nail for firm contact of the fragments But, in spite of firm compression at operation, both fracture stumps undergo absorption after 2—3 weeks They can only approach each other if the screw has a short thread grasping the central fragment but leaving the distal one free If the thread is too long and extends too far into the shank and thus into the distal fragment, the screw will prevent the fracture stumps from approaching each other A gap will develop between the fracture stumps, preventing revascularization, i e, growth of the vessels from the peripheral fragment into the central one

11 Some authors believe that necrosis of the femoral head is the consequence of operative treatment with nail, screw or bone graft and that it does not occur with conservative treatment or in untreated cases Figures 1667—1673 show that total necrosis can also occur after conservative treatment in spite of ideal reduction Figures 1674—1677 show that necrosis occurs very often and

is very extensive, particularly in untreated cases, because of interposition of folds of the capsule and angulation and thrombosis of the vessels in those folds. Figures 1647—1666 show that necrosis also occurs frequently in cases treated by closed reduction and plaster.

12 Some surgeons make early weight-bearing responsible for the crushing of the head Yet, in spite of early weight-bearing, we do not observe more cases of necrosis with crushing of the head than do other surgeons who keep their patients in bed for 2—6 months Bado[1] seems to be the sole exception

13 In septic cases the head dies and usually forms a sequestrum (fig 1779 d) However, bony union may take place and only partial necrosis may develop (fig 1779 e) The joint cartilage is always destroyed in these cases

Recognition of Total Necrosis of the Femoral Head This is comparatively easy in nailed fractures, as we know that a three-flanged nail advances centrally only in the case of total head necrosis (figs 1772, 1779 a, b) Sometimes it can be observed after six weeks and in all cases of developing necrosis after 3—6 months Relatively increased density of the central fragment is particularly noticeable in patients who have not been up (figs 1653, 1662, 1668, 1859) and less so in patients who have started weight-bearing (fig 1772), because the surrounding bones have decalcified to a lesser degree in patients who have been bearing weight Revascularization may take place later on (figs 1667—1673, 1786, 1788, 1796 a—d) or the necrotic head may be absorbed partly (figs 1666, 1785) or totally (figs 1658, 1789)

Change in the position of the fragments is sometimes observed in stable nail osteosynthesis According to Ender,[2] a sclerotic zone at the site of the former fracture line moving slowly medially can be observed in some cases of total necrosis At the level of the acetabular roof a separation of the medial portion of the head takes place and the femoral neck with the greater trochanter moves cranially The result is a "shifting pseudarthrosis" (figs 1856 a—f)

The complaints are, as a rule, only slight in the first two years Mobility may be satisfactory in the beginning, as the joint space remains normal for years — a sign of intact articular cartilage (figs 1662, 1668—1670, 1772, 1859)

Recognition of Partial Necrosis of the Femoral Head This is much more difficult It often cannot be detected in early roentgenograms but becomes visible only when the head flattens opposite the acetabular roof before it eventually collapses Beginning necrosis can, in fact, be detected only histologically and not radiologically Attempts have been made to detect developing necrosis by the administration of radioactive phosphorus and its recognition then in the region of the head with a Geiger counter The depression usually occurs at the site of the greatest stress, viz , opposite the acetabular roof (figs 1778, 1784, 1793—1795, 1797 a—f) It takes place after six months at the earliest. Frequently it first appears in the second or third year,

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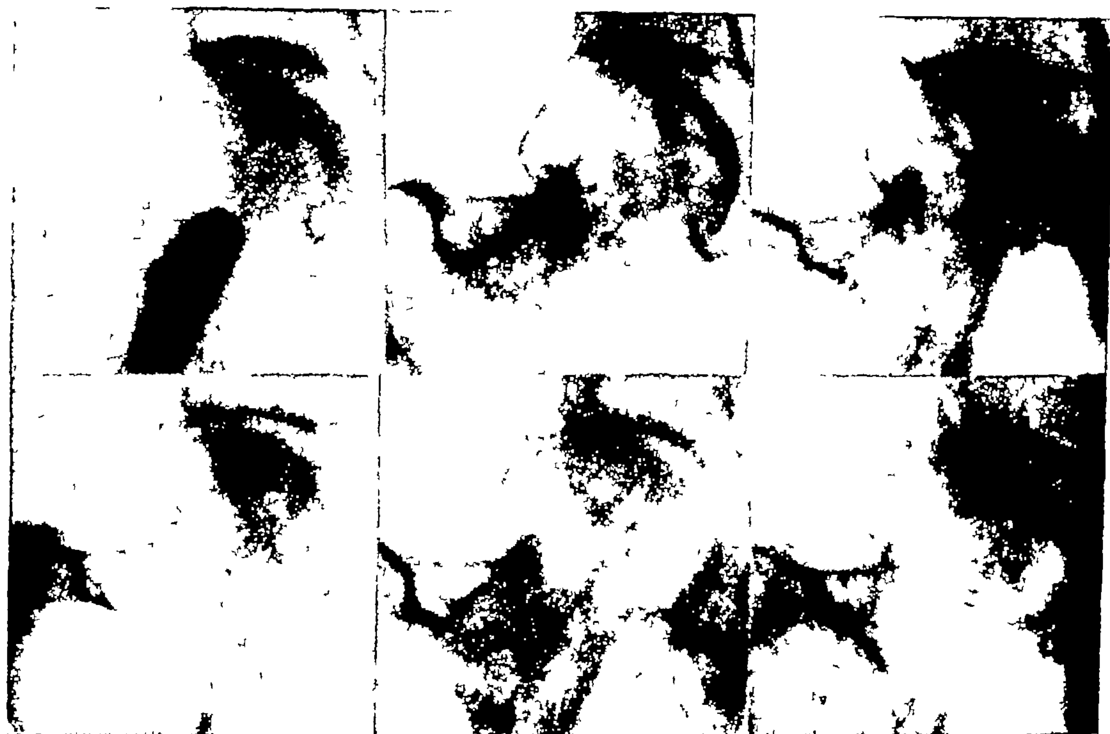
[1] See page 1279

[2] Ender Behandlung der intraartikularen Schenkelhalsbruche und ihre Folgen mit Ergebnissen der Nachuntersuchung, Arch orthop u Unfall-Chir *45* 237—253, 1952

sometimes only in the fourth year We have never seen it begin after the fourth year

The complaints are sometimes negligible, sometimes severe, the latter especially when the joint space is severely narrowed as in figures 1797 e, f

1797 a, April 27, 1942 1797 b, June 4, 1943 1797 c, September 25, 1944



1797 d, May 6, 1946 1797 e, April 25, 1949 1797 f, May 28, 1951

FIGS 1797 a–f —Development of a partial necrosis of the head and arthrotic changes following a nailed medial fracture of the femoral neck in a 42 year old female who sustained an impacted fracture of the femoral neck on November 15, 1939 and was operated on elsewhere on November 20, 1939 From Bohler and Ender (see page 1309, footnote)

FIG 1797 a —The nail, formerly driven into the hip joint, has migrated out to the femoral neck Structure of the head slightly changed Normal width of the joint space

FIG 1797 b —Nail removed

FIG 1797 c —Five years after the accident Slight flattening of the medial part of the head Big cyst and dense foci Slight narrowing of the joint space

FIG 1797 d —Seven years after the accident Small marginal exostosis from the head, 5 mm wide marginal exostosis from the acetabulum

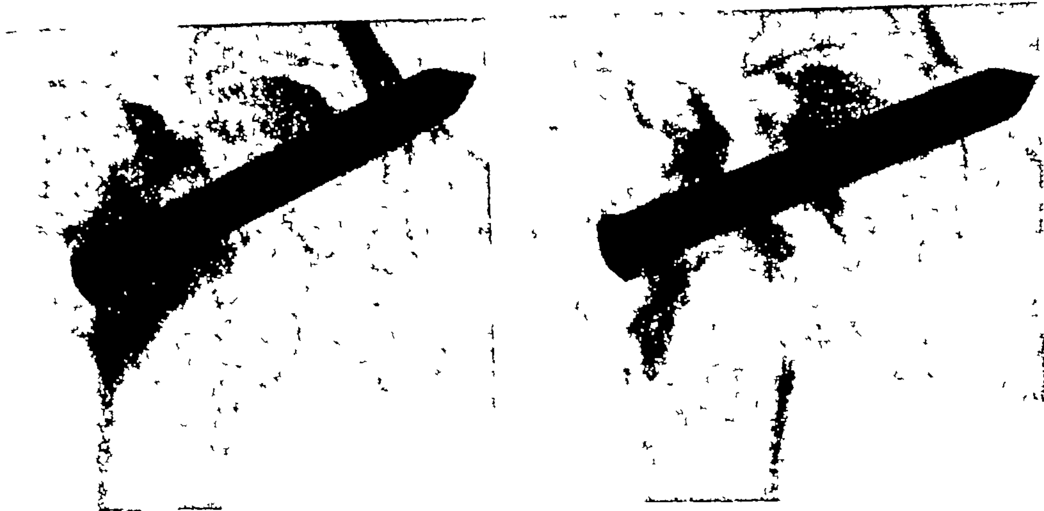
FIG 1797 e —Ten years after the accident The marginal exostosis has increased, the joint space has become narrower

FIG 1797 —Twelve years after the accident Joint space only 1–2 mm The marginal exostosis is 10 mm wide Severe pain for one year Patient walks cautiously, has a slight limp Hip flexion 180°—65° Abduction limited by two thirds, rotation by one-half Arthroplasty

Clinical and radiological findings often differ widely The intensity of pain depends on the degree of irritation of the synovia, the capsular ligaments and the periarticular tissue

Prevention of Total and Partial Necrosis of the Femoral Head Total necrosis can never be prevented completely because it is the consequence of

1798 October 22, 1936 1799







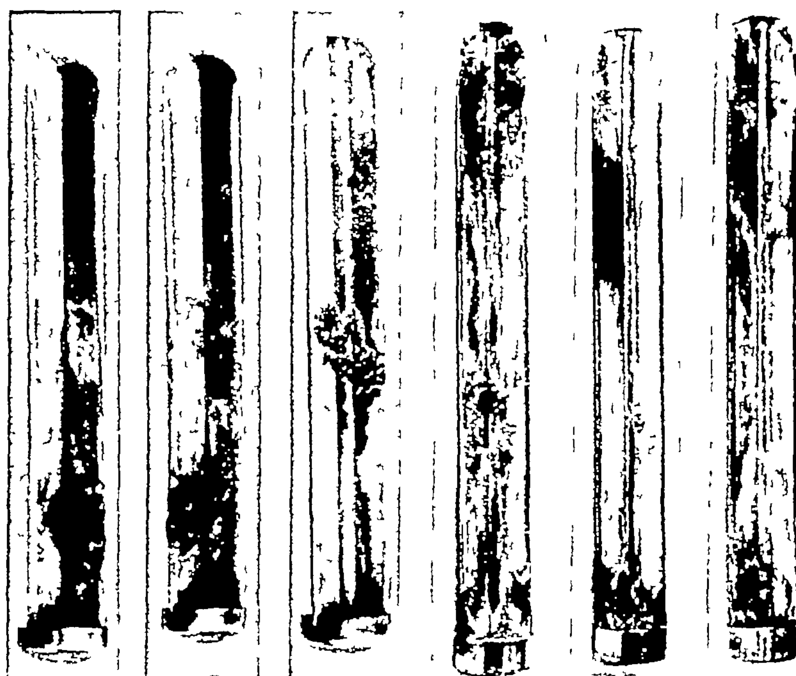
1800, November 3, 1936 1801, January 11, 1938

Figs 1798, 1799—Fracture of the femoral neck in a 60 year old female nailed *at another hospital* two years earlier Non-union The nail penetrates into the pelvis Big cavity of 25 to 28 mm in the trochanteric region The wall of this cavity is sclerosed, whereas the other bones are decalcified The cavity is closed laterally by a bony wall Almost complete destruction of the femoral neck Roentgenograms with the limb in internal and external rotation show how much the nail moves in the big cavity Persistent pain, especially at night Patient can walk only with the help of two crutches

Fig 1800—Check roentgenogram re figures 1798 and 1799, after removal of the nail The head of the nail had been soldered on with an alloy containing copper The big cavity was filled with brownish-black tissue The nocturnal pain disappeared immediately after removal of the nail and the granulations

Fig 1801—Check roentgenogram re figure 1800, after 14 months The formerly sclerosed parts of the wall of the cavity show almost normal density, as do the other bones The femoral neck has disappeared No pain at night Walks well with one stick

the rupture at the time of the fracture of many vessels which nourished the head Percentage and severity of necrosis can be decreased if the causes described on pages 1308—1313 are avoided or removed Revascularization can be promoted by early and complete reduction and by a correct technique of nailing which avoids perforation of the head According to Bado, the use of autogenous bone grafts has proved a particular success (see page 1279) He reports 5 6 per cent cases of necrosis, 9 5 per cent cases of non-union and 5 6 per cent technical faults Ender has found 14% ± 10% cases of necrosis and no cases of non-union among our cases with ideal reduction and correct position of the nail This suggests that accurate reduction and satisfactory



1802 a, b 1803 1804 a—c

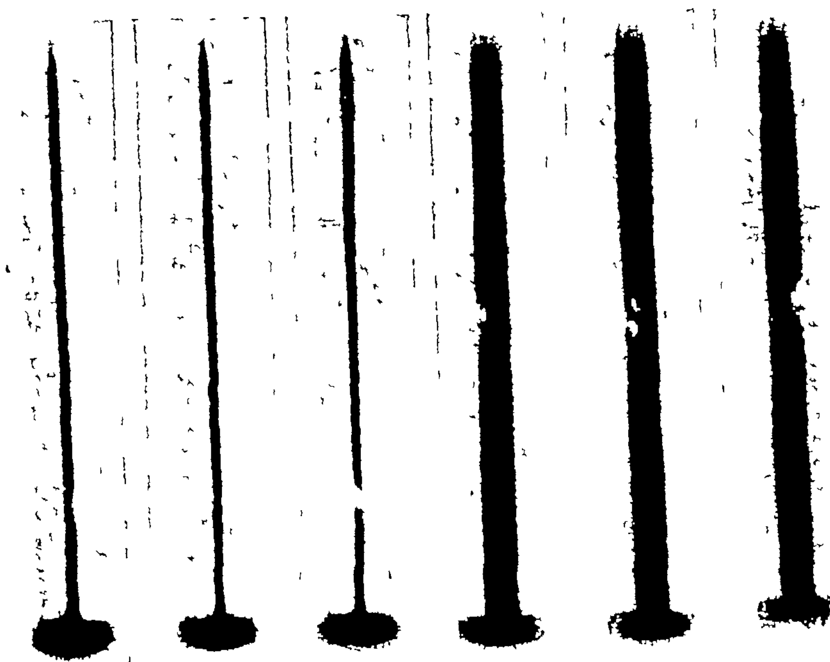
Figs 1802 a, b --Noncannulated three-flanged nail (after Smith-Petersen) removed 2 years and 8 months after operation because of dragging pain in the hip and because roentgenograms showed corrosion of the nail and dense foci in the femoral head One lamella showed a thick covering of rust 15 mm in length After removal of the rust one saw that the metal was completely corroded (compare figures 1805 a—c) After removal of the nail the nocturnal pain subsided immediately and mobility improved (case 9 of Bohler and Jeschke)

Fig 1803 —Cannulated nail (after Sven Johansson) removed $2^1/_2$ years after operation because, though the patient had earlier walked without trouble, pain in the hip developed a year and a half later Roentgenograms then showed a superficial depression of the head and corrosion of the nail Thick layers of rust appeared on two lamellae of the removed nail Roentgenograms of the nail taken in three planes show that one lamella had been completely, and another partially, destroyed by corrosion (compare figures 1806 a—c) After removal of the nail the pain subsided and the joint became largely mobile (Case 64 of Bohler and Jeschke)

Figs 1804 a—c —Cannulated nail (after Sven Johansson) removed $2^3/_4$ years after operation because severe pain had developed, mobility had become limited, and roentgenograms showed extensive destruction of the femoral head and corrosion of the nail The extracted nail showed extensive but not deep corrosion through rust After removal of the nail the pain ceased and the mobility increased (Case 1 of Bohler and Jeschke)

immobilization are all-important Thus the vessels are given an opportunity to bud from the peripheral fragment into the central fragment This process seems to be furthered by an autoplastic bone graft and immobilization in a plaster hip spica and rest in bed for three months, as suggested by Bado

Figures 1557—1563 show that a femoral head which had been severed from all circulation can unite and survive Or, perhaps better, be revived The case was a dislocation of the hip with fracture of the femoral neck The fractured femoral head, completely deprived of all but geographic connection with its neighborhood, was replaced in the acetabulum and connected to the femoral neck by a three-flanged nail Complete revascularization of the femoral head took place with then a secondary depression on the cranial side.



1805 a—c 1806 a—c

FIGS 1805 a—c —Roentgenograms re figures 1802 a—b
FIGS 1806 a—c —Roentgenograms re figure 1803

Psychological Treatment of Patients with Head Necrosis They should never be told that their femoral head has "died," as they are frightened by the very word It is better to tell them that they suffer from arthrotic changes or chronic changes of the joint such as sometimes follow femoral neck fracture Until 20 years ago, all surgeons said essentially that, since necrosis of the head was not yet recognized as an entity at that time One can also say that the complaints may diminish again Only if the complaints increase more and more should an operation be suggested "Caput necrosis" is a good term to use if the condition must be discussed in the presence of the patient

Conservative Treatment of Necrosis of the Head Sometimes the complaints in necrosis with slight depressions are minimal and pain is felt only under severe stresses. The female patient shown in figures 1836 and 1837, for

example, had satisfactory mobility in spite of a rather extensive partial necrosis of the femoral head and was able to go on climbing trips. The patient should, of course, be advised not to put unnecessary strain on the hip The pain is sometimes relieved for a while by X-ray therapy, balneotherapy or anodynes Vasodilatory drugs are probably of no value Massage and passive movements must strictly be warned against, since they irritate still more a joint already painful and limited in motion

Treatment of Roentgenographically-Positive Necrosis of the Femoral Head With Weight-Bearing Splints Many surgeons prescribe orthopedic appliances in these cases They should not, however be used in elderly patients, as these splints are too heavy and probably serve no purpose inasmuch as rebuilding of the head takes 3 to 7 years, as shown in figures 1669—1673 Up to now, nobody has proved that a head necrosis can be healed by use of an orthopedic splint In children and juveniles, weight-bearing splints may be helpful — as, for example, in Calvé-Legg-Perthes disease

Primary Excision of the Femoral Head to Avoid Head Necrosis Some surgeons excise the femoral head immediately after the accident and replace it with an artificial head in order to avoid necrosis and non-union This is a most radical procedure But we feel that this likely causes still more complications, so we urgently advise against it

Treatment of Necrosis of the Head by Removal of the Three-Flanged Nail The nail should be left in place in the case of partial necrosis, since the depression and the pain usually increase after its removal, whereupon the patient blames the surgeon who did the removal Neither should the nail be removed in total necrosis with penetration of the nail into the hip joint unless such removal is followed by arthrodesis or arthroplasty

Operative Treatment of Necrosis of the Head If the complaints increase, if severe contractures develop and the pain is also marked at rest and at night, a subtrochanteric osteotomy can be tried as shown in Vol I/figs 320—322 and in figure 1879 With poor mobility, severe joint changes and persistent severe pain, an arthrodesis (fig 1565 e) or an arthroplasty (fig 1565 a—c) is to be preferred

NON-UNION OF THE FEMORAL NECK

Causes of Non-Union of the Femoral Neck

Before 1902, essentially all adduction or varus fractures of the femoral neck resulted in non-union, since one did not yet know how to reduce this fracture and to retain the good position achieved for a sufficiently long period The poor blood supply of the central fragment had been held responsible, as well as the absence of callus-forming periosteum, interposition of folds of the capsule, and bone atrophy in the elderly patient The poor blood supply, the bone atrophy and the absence of a thick periosteal covering, however, only cause a certain delay in the healing, while interposed folds of the capsule (figs 1676, 1677) are no longer interposed after correct reduction. Experience

of the last 50 years has shown that, like all other fractures, this one will unite well after good reduction and sufficiently long immobilization Reduction of recent fractures is usually, but not always, quite simple, whereas uninterrupted immobilization in a big thoracopelvic plaster hip spica for six months is technically difficult and is actually dangerous in old, markedly obese or weak persons In most cases of non-union I have seen, the treatment was inadequate, i e, the reduction was not accurate and/or immobilization was poor or continued for too short a time Many a time the fracture was not diagnosed at all, so that no reasonable treatment was given

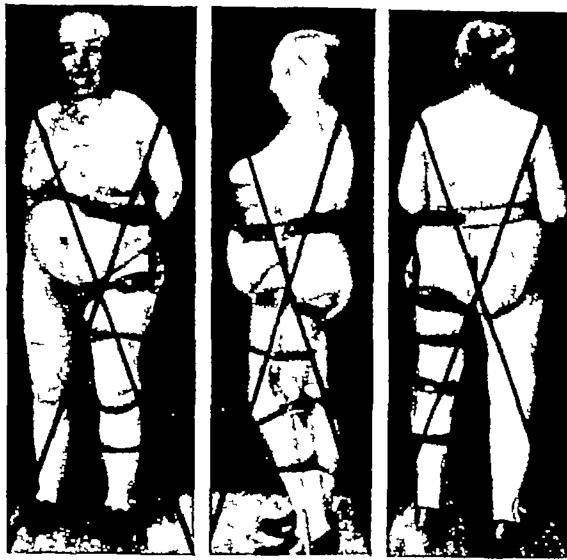
The cause of non-union without concomitant necrosis of the head after a nailed fracture of the femoral neck is frequently a poor reduction and always an unstable osteosynthesis (fig 1778)

Recognition of Non-Union of the Femoral Neck

Recognition of non-union in the roentgenogram is very easy if both fracture stumps are sclerosed and there is a wide gap between them (figs 1838, 1839) or if the fracture surfaces do not touch each other (figs 1760, 1761, 1847) It is still simpler if the femoral neck has disappeared and the greater trochanter has slipped upwards as in figures 1816, 1817, 1852 and 1853 Recognition is difficult if only one roentgenogram — an A-P view with the limb in external rotation — is available, as in figures 1814 or 1830 A roentgenogram in internal rotation, however, shows a wide gap between the sclerosed fracture surfaces, as in figure 1815 Often non-union is detectable in the lateral view only, as in figure 1850 a, whereas it cannot be recognized with certainty in the A-P view (fig 1850)

It may be rather difficult to decide whether a nailed fracture of the femoral neck has united or developed non-union if the central part of the fracture site is covered by projection of the three-flanged nail as in figures 1849 and 1856 e Especially in figure 1856 e the fracture seems united, but figure 1856 f shows that six months later total necrosis of the femoral head and non-union of the femoral neck are present If the fracture line remains visible in spite of the nail, as in figures 1798 and 1799, its recognition is easy

For a definite diagnosis, A-P roentgenograms with the limb in external and internal rotation and a lateral view are necessary If these show bony consolidation of the fragments and equal structure of the bone in all three views, as in figures 1826—1829, 1834—1837 and 1842—1845, definite bony union is indicated If a sclerosed zone at the site of the former fracture line is visible, as in figures 1850 and 1856 e, there is reason to suspect that the fracture has not yet consolidated Sometimes an A-P roentgenogram showing the whole pelvis and similar projection with the patient in the lithotomy position (figs 1588, 1592) should be taken to allow comparison with the sound side



Figs 1807—1809—A 78 year old female who fell eight years earlier On the basis of the pain, a diagnosis of fracture of the femoral neck was made without X-ray examination Six weeks later she was discharged with this orthopedic splint which she later wore from time to time She could walk much better without this appliance than with it Roentgenograms show that the femoral neck has never been broken Old arthrotic changes present in both knee joints, more severe on the left than on the right Pain in the knees, no pain in the hip Hips are mobile to equal extent On the basis of the supposed fracture of the femoral neck, a disability pension of 100 per cent had been drawn for five years, later one of 60 per cent



Fig 1810—A 70 year old, well-developed man with non-union of fracture of the right femoral neck Real shortening 4 cm Severe hip contracture in adduction, flexion and external rotation Flexion contracture of the knee joint Because of the adduction deformity the pelvis stands higher on the injured side The X-ray findings are similar to those in figure 1866

Fig 1811 Owing to the flexion deformities of the hip and knee, he can walk only when he leans far forward and uses a cane The heel of the injured leg can touch the floor only if the sound leg is markedly flexed at hip and knee

Fig 1812—Because of the severe adduction deformity, the apparent shortening amounts to 10 cm

Fig 1813 If the apparent shortening is overcome by a platform 10 cm high he still cannot stand upright because of the flexion deformities of hip and knee





1814 1815

FIG 1814—Two year old non-union of femoral neck shown in A-P roentgenogram with the limb in external rotation This view does not allow a definite decision as to whether or not the fragments have united

FIG 1815—Comparison roentgenogram re figure 1814, taken with the limb in extreme internal rotation The view clearly shows the "polished" bony surface at the base of the femoral neck The density of the head equals that of the neighboring bone, showing that the head is alive It would be easy to reduce this fracture by longitudinal traction and to nail it (compare with figures 1838—1846)





1816 1817

FIG 1816—Non-union after a femoral neck fracture of only ten weeks standing, sustained by a 56 year old tabetic male in a fall The femoral neck has completely disappeared What remains of the head shows a smoothly polished fracture surface The greater trochanter has broken transversely Extensive ossification of muscles Mobility of joint free in all directions Because of the tabes, this case must not be operated on

FIG 1817—Non-union after a 15 year old fracture of the femoral neck sustained by a 59 year old female Treated with adhesive-tape traction of 3—5 Kg for two months Shortening of 9 cm The neck has disappeared The trochanter lies extraordinarily high Atrophy of bone No nerve disturbances Pain at hip and knee Walking difficult, possible only with support Operation offers no good prospects No improvement by supporting brace

1818 November 14, 1941 1819



1820 August 24, 1943 1821

FIG 1818—Medial fracture of the femoral neck with coxa vara of 100° Sustained by a 43 year old physician in a fall

FIG 1819—Check roentgenogram re figure 1818, after operation *at another hospital* Without reduction and without the use of an extension table, three spikes were driven in with the neck in varus (110°) Lateral roentgenograms were not taken either before or after operation Plaster hip spica after operation for two months Because the fracture had not united after this treatment and persistent pain had developed in the hip, 1½ years after accident a fibular graft was implanted, again without previous reduction Plaster hip spica for three months After removal of the plaster the fracture was not united and the graft had broken

FIGS 1820, 1821—Check roentgenograms re figure 1818, two years later *Fibrous* union of the femoral neck Coxa vara of 100° seen in the anteroposterior view Cranial displacement of the distal fragment, the greater trochanter lying higher than the acetabular roof Fragments of the graft, its point of insertion having been not in the long axis of the femoral neck but cranial to it, are visible in the trochanteric region and in the femoral head The lateral view shows a ventral displacement of the distal fragment by more than half of the shaft's width and anterior angulation of about 70° The femoral head shows dense areas and decalcified areas not surrounded by sclerosed bone This is a sign that there are no cysts but well-nourished regions of bone Shortening of 2 5 cm Wears a supporting brace and walks only with difficulty with the help of two canes figures 1818—1821, 1826 and 1827 have been taken from a paper by Jorg Bohler [1]

[1] Bohler, Jorg Zur Behandlung der veralteten Bruche und Pseudarthrosen des Schenkelhalses, Schweiz med Wchnschr *77* 1333, 1947

1822, October 12, 1943 1823, October 15, 1943



1824 November 16, 1943 1825

FIG 1822 —Check roentgenogram re figure 1820, seventeen days later after traction with at first 12 Kg, later 15 Kg Coxa vara improved to 115° The fragments of the graft are in alignment, no longer showing caudal angulation Diastasis of 15 mm in the hip joint

FIG 1823 —Check roentgenogram re figure 1822, after reduction of the fracture under spinal anaesthesia with gradual manipulation up to extreme abduction and internal rotation The fragments are now well apposed Coxa vara has disappeared The fragments of the graft show an angle open cranially

FIGS 1824, 1825 —Check roentgenograms re figure 1823, after insertion of a three-flanged nail Good alignment in both views Correct position of the nail in the center of the femoral head In spite of impaction there is a wide gap between the fragments The patient got up without a plaster cast four weeks after operation He could walk with the help of two canes after eight weeks Five months after operation he took up his work as a physician, being able to walk without pain and without a limp

Prevention of Non-Union of the Femoral Neck

Non-union can be prevented by correct reduction and sufficiently-long, uninterrupted immobilization, i e, usually for 6—12 months. Sometimes a still-longer period of immobilization is necessary Bony union can be achieved with correct use of continuous traction (figs 1615—1625), with a plaster cast

(figs 1643—1646), or by the easiest and most reliable way, i e, a nail or screw(s) (figs 1724—1729)

Stable Osteosynthesis After correct reduction, sufficient stability is achieved (1) if the nail is broad enough, (2) if its position is correct, i. e. if it lies in the center of the head and at an angle of 125°—135°, (3) if it catches the head sufficiently, (4) if it approaches the articular cortex of the head within 6—10 mm, and (5) if it is firmly anchored laterally in the greater trochanter

Unstable Osteosynthesis It is unstable· (1) If a wedge has broken out of the calcar femorale (fig 1778 a), (2) In fractures of Pauwels' group III provided the nail is not firmly anchored laterally (fig. 1778 b), (3) If the nail lies too flat and the cortical bone at the lateral side of the trochanter has been fractured (fig 1778 c), (4) If the nail lies too far ventrally or cranially and if it moves (fig 1778 d), and (5) If the nail has broken owing to varus position of the fragments when it lies too flat (fig 1778 e). In the conditions referred to in points 1—3, sufficient stability can be achieved by attaching a trochanteric plate to the nail (fig 1879) Causes 2—5 are due to technical mistakes which must by all means be avoided

It is very important not to remove a nail before definite bony consolidation has been proved by adequate A-P roentgenograms with the limb in external and internal rotation and by a good lateral view This may take 1—2 years in a case of circulatory disturbance in the femoral head. The fractures of the femoral neck shown in figures 1849 and 1856 e would probably have united if the nail had been removed or a transposition osteotomy had been performed

Complaints in Non-Union of the Femoral Neck

Complaints of varied degree arise if fracture of the femoral neck does not heal with bony union The degree of pain depends upon the firmness *of the union of the fragments, upon the position of the limb in the* hip joint (e g, presence of contractures), and upon whether the femoral head lives or a total or partial necrosis has developed All these patients limp, can usually walk only short distances, and suffer pain in the hip radiating towards the knee on walking and sometimes even at rest Without adequate treatment, adduction, external rotation and flexion contractures frequently develop With severe adduction and flexion deformity the patient cannot reach the floor with his heel, and walking is possible only with the help of crutches The gait is particularly bad if extension of the knee is limited at the same time, as shown in figures 1810—1813 A flexion contracture of the knee is a severe handicap even with a freely-mobile hip joint However, there are also people who are almost fully capable of work in spite of their non-union of the femoral neck and who therefore need no treatment

Treatment of Non-Union of the Femoral Neck

Some surgeons recommend conservative, others operative treatment

Conservative methods are· (a) Use of weight-bearing splints, (b) Injection of "callus-forming" substances

1826 July, 4, 1944 1827



1828 March 6, 1954 1829

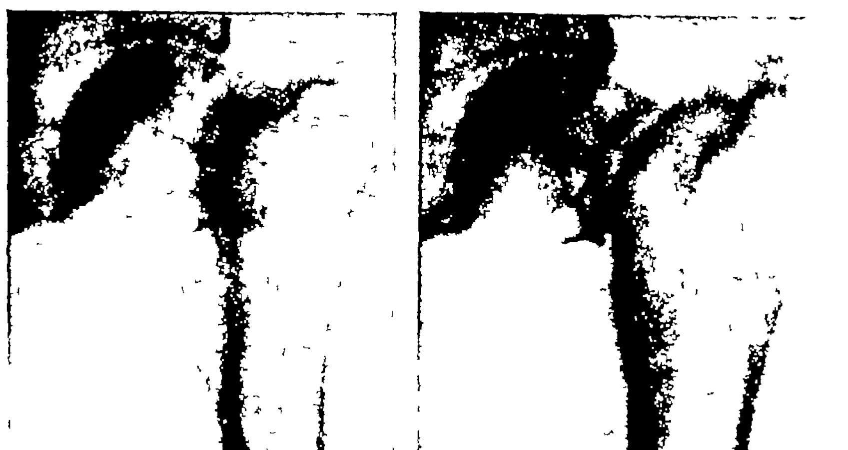
FIGS 1826, 1827 —Check roentgenograms re figures 1824 and 1825, eight months later Bony union in satisfactory position The fracture line has been bridged

FIGS 1828, 1829 – Check roentgenograms re figures 1824 and 1825, ten and a half years later The three-flanged nail was removed one year after operation The femoral head shows normal form Uniformity of calcium content has increased relative to findings in figures 1820 and 1821 Normal width of joint "space" Marginal exostosis from the cranial side of the femoral neck as before operation Walks without trouble Full range of active motion

Operative methods are (a) So-called "reconstruction" operations, (b) Subtrochanteric osteotomy, (c) Nailing of the femoral neck, (d) Hip arthroplasty, and (e) Hip arthrodesis

Treatment of Non-union of the Femoral Neck With Orthopedic Braces They still are prescribed comparatively often We have seen no patient whose fracture or non-union of the femoral neck has healed as a result of the patient's using an orthopedic brace We have seen, however, many patients who have painfully dragged such braces around They had been told not to take a single step without the appliance lest a severe displacement of the fragments might occur They had also been told to put it on even when

1830 November 12, 1934 1831





1832 May 7, 1935 1833

FIGS 1830, 1831—Fibrous union with coxa vara and shortening 10 months after a fracture of the femoral neck in a 47 year old female Left picture made with limb in external rotation, right picture with limb in internal rotation With internal rotation the fracture gap is clearly visible The head shows normal outlines and is alive A great part of the neck has remained, the fracture surfaces are in contact Decalcified region in the caudal part of the femoral head Was treated *elsewhere* with wire traction of 10 Kg for 8 weeks in bed, later with an orthopedic splint in which she walked poorly with the help of two canes Pain in the hip Since correction of the varus position could not be achieved in continuous traction, the angulation of the fragments was corrected under general anesthesia by cautious manipulation in extreme abduction and internal rotation Then nailing Since there is no lateral displacement, we should now carry out a pertrochanteric osteotomy and attach a plate to the nail as in figures 1879, 1980c

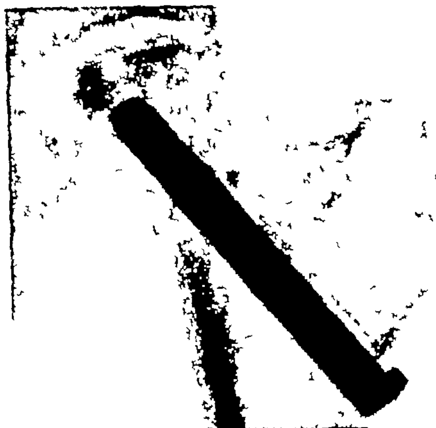
FIG 1832, 1833—Check roentgenograms re figures 1830 and 1831, after removal of the short plaster spica (used by us at that time) six months after operation Bony union in satisfactory position The fracture gap is almost completely bridged by bone Cranial to the tip of the nail a small cyst is visible in the bone (rust damage, re figures 1803 and 1806a—c) One week later she could walk very well without pain and without cane All motions of hip normal

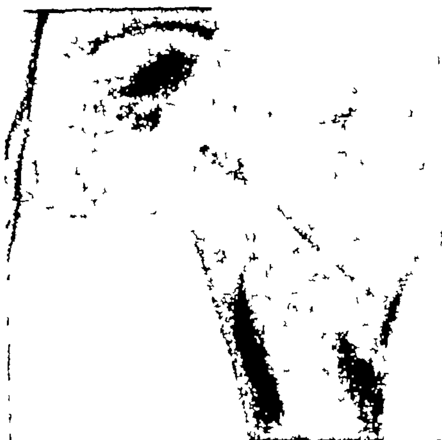
going to the toilet at night We have liberated most of these patients Out of consideration for the responible surgeons, we told the patients after thorough clinical and radiological examination that the healing had advanced

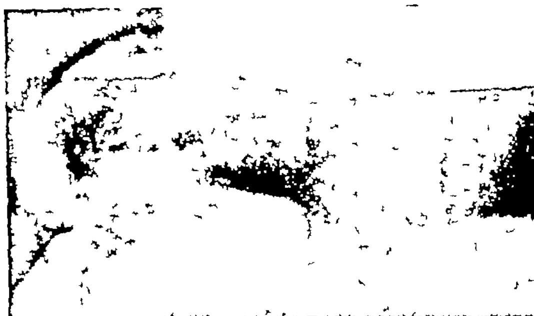
1834, June 2, 1936,



1835, July 5, 1937







1836 November 27, 1937 1837

FIG 1834 —Check roentgenogram re figures 1832 and 1833, one year later The femoral head shows increased calcium content and a small depression in its cranial part There is a relatively radiolucent zone limited by a sclerosed line along the nail Dragging pain in the hip for five months Hip flexion normal, abduction and rotation limited by one-third

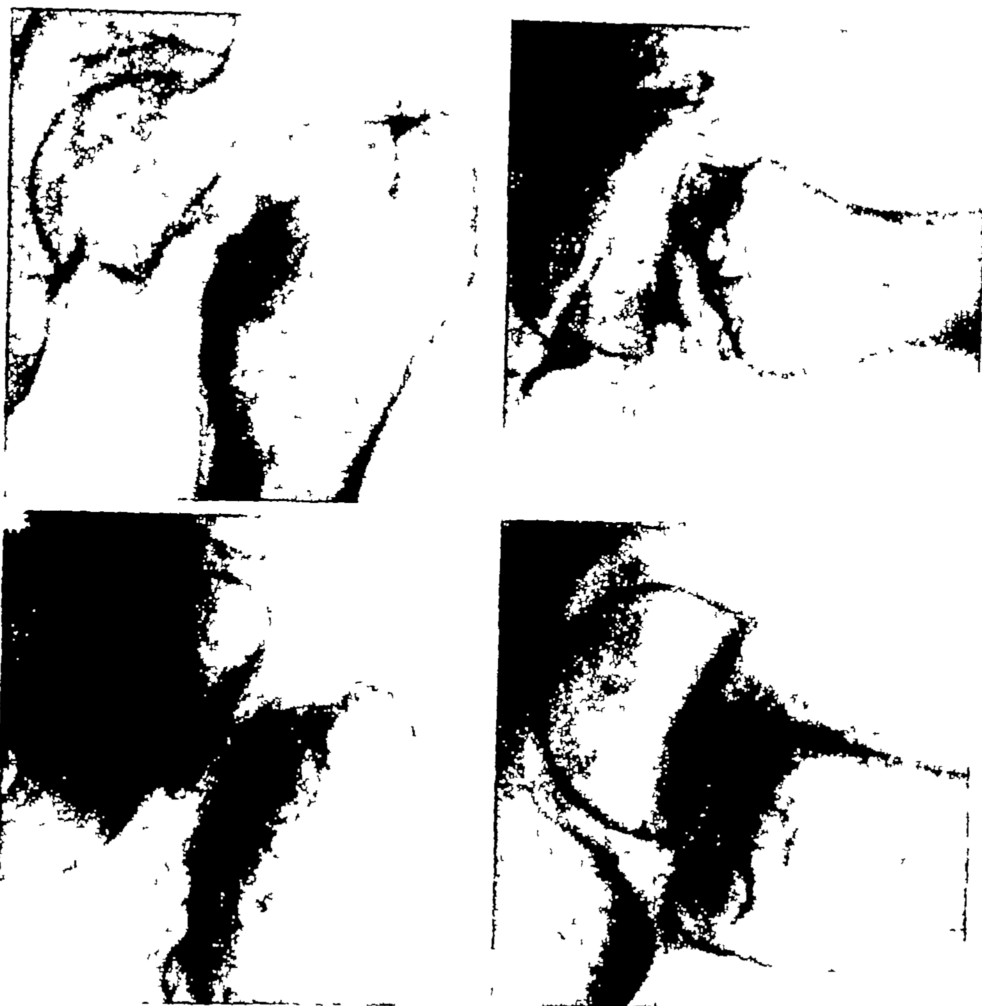
FIG 1835 —Check roentgenogram re figures 1832 and 1833, two years later The cranial part of the head further depressed and more dense Flexion normal Abduction half, rotation limited by one-third The complaints have slightly increased

FIG 1836 —Check roentgenogram re figure 1835, five months after removal of the nail The surface of the head has become smoother The track of the nail is clearly visible Motion has increased, pain has almost disappeared Patient has begun mountain-climbing again

FIG 1837 —Comparison lateral roentgenogram re figure 1836 The ventral part of the head is irregular and dense Two lamellae of the removed nail were severely corroded (see figures 1803, 1806 a—c)

so far that further displacement need not be feared any longer, that they might bear weight now without the appliance, and that if this caused no major disturbances they should extend walking without it by one hour every day and discard it altogether after two weeks Most patients reported with pleasure that they walked much better without the appliance In satisfactory general and local conditions we have then recommended an osteosynthesis.

1838 February 12, 1946 1839



1840 February 16, 1946 1841

Figs 1838, 1839 Established non-union eleven months after a fracture of the femoral neck in a 53 year old farm wife, treated only with rest in bed and fomentations Patient's height 157 cm, weight 70 Kg Uniform decalcification of both fragments The head shows no sclerotic foci and no cysts it is well nourished Both fracture surfaces are sclerosed The neck has been absorbed Patient walks with two crutches Shortening of 3 cm Patient cannot actively lift this limb Passive motion of the hip through a greater range than normal

Figs 1840, 1841 —Check roentgenograms re figures 1838 and 1839, four days later in tibial tubercle pin traction of 8 Kg Lengthening of the limb by half the width of the femoral neck Dorsal displacement of the neck Longitudinal traction therefore reduced to 6 Kg

It is unreasonable and irresponsible to prescribe weightbearing appliances for patients who have been in bed because of their poor general condition for weeks and months If the insurance company asks whether such an appliance is absolutely necessary and whether it suits the purpose, the answer must be "No"

We have also seen patients who, carrying the wrong diagnosis of fracture of the femoral neck, have worn a weight-bearing appliance years and even decades The roentgenograms shown in figures 1807—1809 showed that the femoral neck in that patient had never been broken

1842 February 8, 1949 1843

1844 March 4, 1954 1845

Figs 1842, 1843—Check roentgenograms re figures 1838 and 1839, three years after nailing Fragments have united in good position Good position of the nail in both views No complaints

Figs 1844, 1845—Check roentgenograms re figures 1838 and 1839, eight years after operation and five years after removal of the nail Bony consolidation at site of former non-union Femoral neck shortened Normal density No complaints Patient works hard all day on the farm in the house and in the fields Active motion of hip joint normal except for slight limitation of internal rotation and abduction

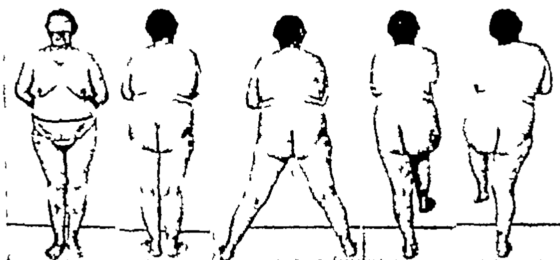


Fig 1846—Photographs re figures 1838—1845, five years after operation When the patient stands on the left leg, the pelvis tilts to the right (positive Trendelenburg sign) No limitation of motion discernible

1847 January 12, 1938 1847 a









1848 March 9, 1938 1848 a

FIGS 1847, 1847 a Six month old non-union at the base of the femoral neck in a 40 year old scaffold worker who was hit on the thigh by a post Treated *elsewhere* at first with continuous traction, then with a big Whitman plaster cast but *without previous reduction* The anteroposterior roentgenogram shows a coxa vara of 90°, the lateral view shows antecurvature with a 75° angle open dorsally The fragments are in contact only along one edge The dorsal tip of the distal fragment has bored a deep hole at the junction of the neck and the head Because reduction was not possible in continuous traction, the hip joint was exposed for open reduction of the fragments Then a nail was inserted

FIGS 1848, 1848 a—Check roentgenograms re figures 1847 and 1847 a, five weeks after nailing The three-flanged nail lies well in both views, at an angle of 125° with the shaft and approximately in the center of the head Its tip approaches the surface of the head to within 6 mm Patient got up and started walking with two canes 14 days after operation

Treatment of Non-Union of the Femoral Neck with "Callus-Forming" Remedies Formerly we saw patients with non-union of the femoral neck who had been treated with injections of tincture of iodine, osmic acid, zinc chloride, calcium chloride, Ossophyt, fibrin, the patient's own blood, bone ashes, emulsion of periosteal tissue and many other substances injected into the hip joint These



1849
November 22, 1939



1850
December 3, 1939



1850 a
December 3, 1939



1851
December 28, 1939



1852
September 29, 1942



1853
May 28, 1952

FIG 1849—Check roentgenogram re figure 1848, 20 months later The fracture line is not bridged The fracture surfaces appear a little sclerosed The tip of the nail has approached the surface of the head to within 2 mm, a sign of caput necrosis Coxa vara of 115° Can walk 3 Km without pain and without a cane

FIGS 1850 and 1850 a—Check roentgenograms re figure 1849, eleven days after removal of the nail The track of the nail shows clearly a 5 mm cranial displacement of the distal fragment, a sign that the fracture has not united The cranial part of the head has separated from the caudal part and lies in the joint as a sequestrum The lateral view shows the gap of non-union With movement of the limb a "cracking" is felt in the hip joint

FIG 1851—Check roentgenogram re figure 1850, five weeks after removal of the nail The track of the nail in the distal fragment is displaced cranially 20 mm Patient able to walk only with two canes and with pain after removal of the nail In caput necrosis the nail should never be removed, since this always causes the situation to deteriorate If severe pain supervenes, arthroplasty — or, better, arthrodesis — should be performed

FIG 1852—Check roentgenogram re figure 1850, three years later 45 mm cranial displacement of the distal fragment

FIG 1853—Check roentgenogram re figure 1850, $12^1/_2$ years later Cranial displacement of distal fragment by 60 mm Walks with difficulty and with the help of two canes

cases are becoming less frequent Internal treatment or intravenous injections of calcium, Vigantol, hormones and similar drugs are still often resorted to, although they are of no use at all. Never up to now has roentgenographic evidence been published showing positive results of such treatment So the patients had better be spared the inconvenience and the discomfort and the expense

Treatment of Non-Union of the Femoral Neck with So-called "Reconstruction Operations." Since many surgeons had believed until a short time ago that non-union of the femoral neck could never heal with osseous union, they removed the femoral neck, placed the stump of the femoral neck into the acetabulum and transplanted the greater trochanter distally, as did Whitman, Albee, Anschutz and others Lexer in addition used the rest of the femoral head to form a new acetabular roof Restitution cannot be achieved by these methods

Treatment of Non-Union of the Femoral Neck with the Pertrochanteric Closed Osteotomy. It was intoduced by Lorenz, Schanz, v Baeyer, Putti and Pauwels Lorenz had called it "bifurcation" The femur is chiseled through just above the lesser trochanter by an open or "closed" operation, and the distal fragment is displaced medially Then a plaster hip spica is applied The femoral neck and head thereafter bear no weight ("propping osteotomy")

Pauwels in 1929 described an osteotomy with shifting of the weight-bearing stresses His method consists in removing a wedge from the lateral side of the femur Thus the originally vertical gap of non-union is tilted into the normal weight-bearing line of the femoral neck Shearing stresses are thus converted into compressive forces This often leads to bony union as the roentgenograms of the female we operated on in 1926 show (Vol I/figs 319—322) The technique of the operation is described on page 1098 and the end-result is shown in figures 1871—1873 In the same way the varus position of the two-year-old epiphyseolysis of figures 1925 until 1936 was corrected in 1924 We performed this operation frequently in the years 1921 to 1932

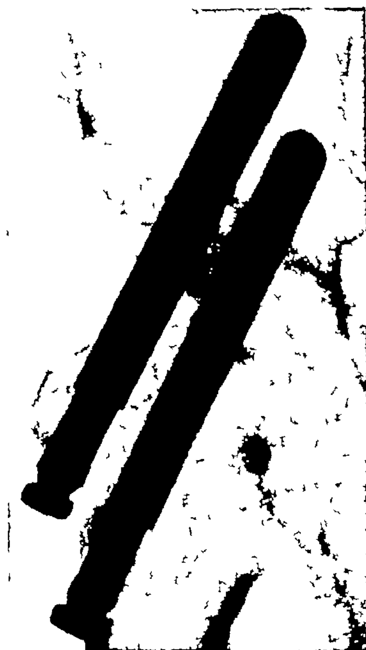
Treatment of Non-Union of the Femoral Neck by Open Subtrochanteric Wedge Osteotomy with Nail and Plate At present we usually do an open V-shaped or transverse wedge osteotomy with nail and plate as shown in figure 1879 The use of nail and plate makes a plaster cast unnecessary Before operation the A-P roentgen image of the femur is traced and cut out The tracing paper is incised at the caudal border of the lesser tochanter right across to the medial margin as in figure 2578 The distal or shaft part is abducted until the angle between the femoral neck and shaft amounts to 140° The overlapping of the two then shows the width of the bone wedge to be removed (figure 1926) The patient is placed on the screw traction apparatus and the three-flanged nail is inserted as in a recent fracture of the femoral neck (figs 1701—1727) A notch in the long axis of the shaft is cut into the lateral aspect of the femur so that after removal of the wedge one may easily determine through exactly how many degrees the limb must be rotated internally in those cases in which there was originally marked external rotation Caudal to the head of the nail a wedge of the determined width is chiselled

out of the femoral shaft Two Steinmann pins are driven into the greater trochanter for adduction of the central fragment as in figure 1929, until the lateral edges of the osteotomized bones come into contact If only one Steinmann pins is used it sometimes ploughs through the soft bone In the case of external rotation the femur is rotated internally The plate is screwed onto the three-flanged nail and fixed to the femur with screws (fig 1879) As a rule, the patients are allowed up without plaster three weeks later

Treatment of Non-Union of the Femoral Neck with the Three-Flanged Nail. Formerly, use of a bone graft was generally believed necessary to heal a



1854, May 29, 1951



1855, March 29, 1954

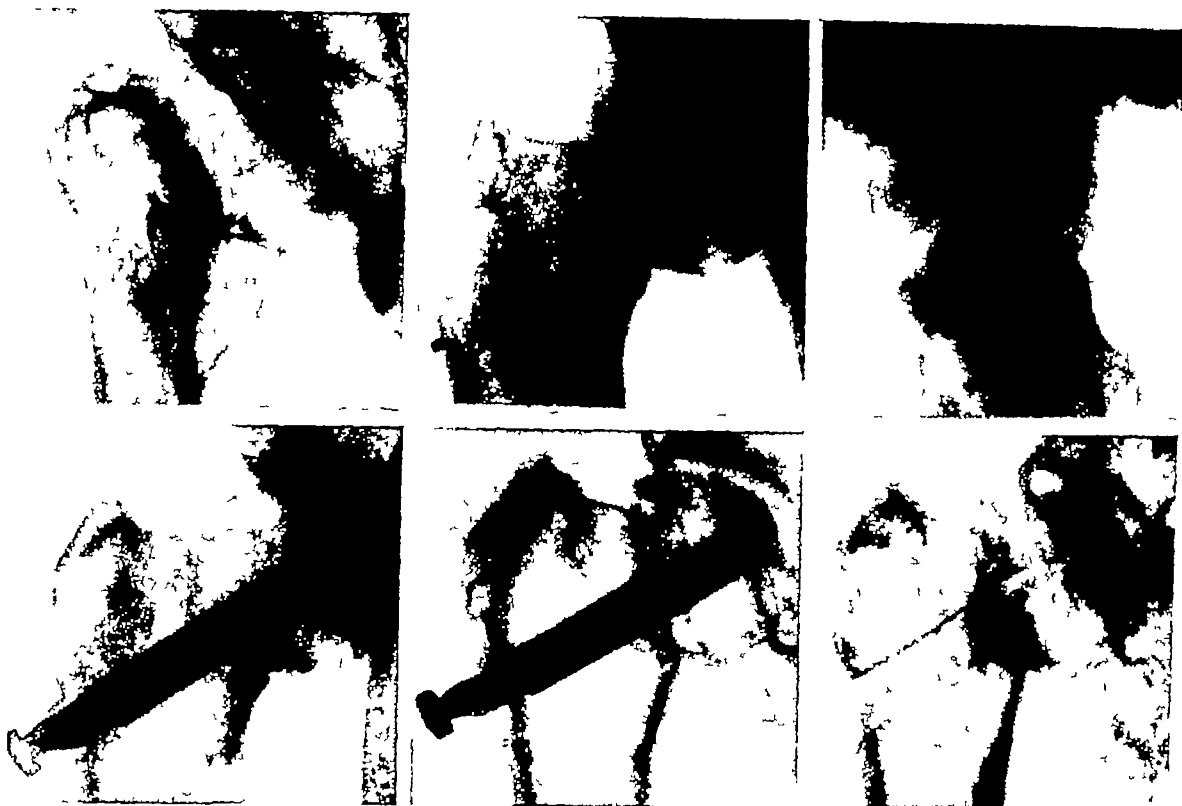
FIG 1854 —Excision of the femoral head because of painful aseptic necrosis following nailing of a femoral neck fracture Arthroplasty with a translucent glass head Pain persisted so the glass head was removed three years later and arthrodesis performed

FIG 1855 —Check roentgenogram re figure 1854, after arthrodesis The glass head was removed and the acetabular roof and the femoral neck were freshened The femoral neck was placed in the acetabulum and fixed with two three-flanged nails 15 cm long The remaining cavity was filled with chips from the bone bank Patient could walk without pain with the help of two canes six weeks later

non-union of the femoral neck Since 1932 we have treated about 100 cases with the extra-articular nailing method, viz , without freshening the bone ends and without bone-grafting Bony union has occurred in 87 per cent The 13 per cent failures have been due to our mistakes in operating on the basis of improper indications and to faulty technique Thus, contrary to the general opinion in former times, non-union of the femoral neck carries a very favorable prognosis

Correct selection of the cases for operation is essential to good results General and local conditions must be good There are the same contra-indications as in recent fractures of the femoral neck (see page 1265) When

1856 a, October 12, 1936 | 1856 b, October 21, 1936 | 1856 c, October 12, 1936



1856 d, October 21, 1936 | 1856 e, December 3, 1937 | 1856 f, June 5, 1938

FIG 1856 a—Recent medial adduction or varus fracture of the femoral neck in a 73 year old female

FIG 1856 b—Check roentgenogram re figure 1856 a, after nine days on the screw traction apparatus Three lead reference markers are seen Fracture appears well reduced

FIG 1856 c Lateral roentgenogram re figure 1856 a The distal fragment is in contact with the central one by its ventral edge only Nailing in this position usually fails to produce bony union If the fracture surfaces cannot be apposed properly, it is usually better to remove the femoral head and do an arthroplasty

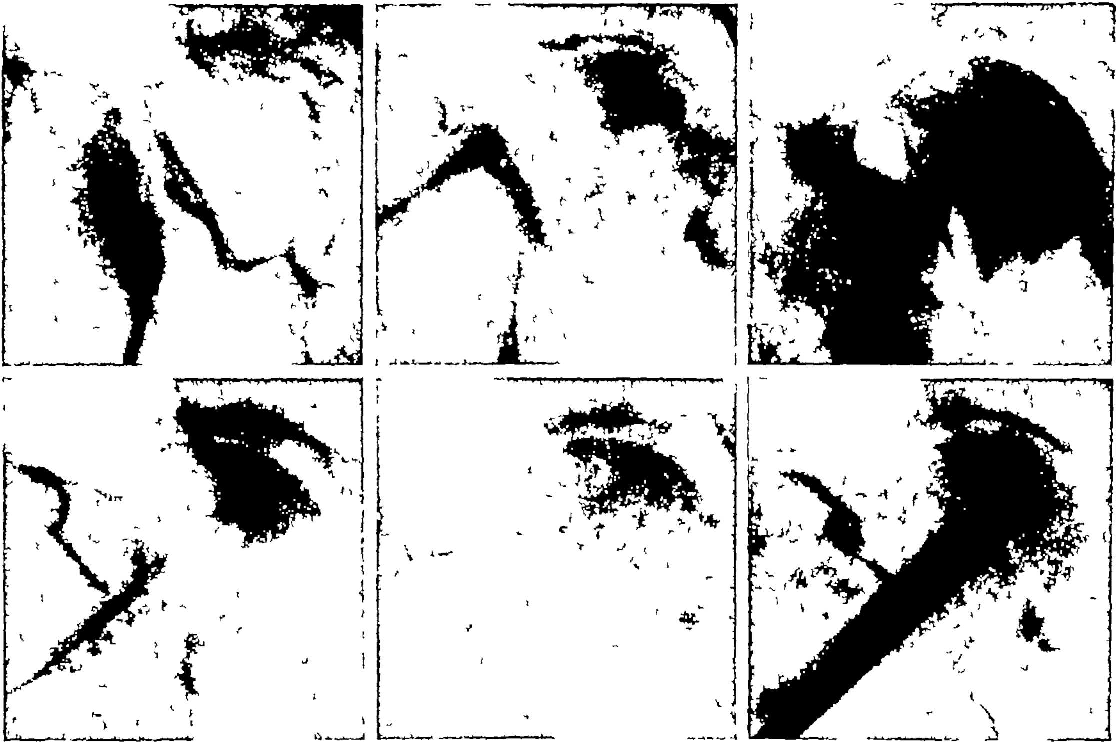
FIG 1856 d—Check roentgenogram re figure 1856 b, after insertion of the three-flanged nail It has been placed in the center of the head in both views The tip of the nail approaches the surface of the head to within 10 mm Patient could walk well with one cane four weeks later

FIG 1856 e—Check roentgenogram re fig 1856 d, thirteen months later The nail has approached the surface of the head to within 3 mm This is a definite sign of total necrosis The fracture appears to have united Patient could walk without pain for three hours at a time Motion of the joint was slightly limited The nail was removed

FIG 1856 f—Check roentgenogram re figure 1856 e The fragments have united but a "shifting pseudarthrosis" has developed further medially at the junction of the revascularized and the necrotic parts of the head Limping and pain on walking developed after removal of the nail In caput necrosis the nail should not be removed unless arthroplasty — or, better, arthrodesis — follows

their general condition is good, even people over 70 years old can be operated on Our oldest patient was 81.

1857, February 12, 1946 1858, September 24, 1943 1859, April 9, 1951



1857 a, March 4, 1954 1858 a, March 6, 1954 1859 a, June 18, 1952

Three cases of non-union of the femoral neck with different circulatory conditions of the head and their treatment Taken from Bohler and Ender (see page 1309, footnote)

FIG 1857 Eleven month old non-union with sclerosed bone ends Evenly distributed decalcification of the head is a sign of good circulation

FIG 1857 a —Check roentgenogram re figure 1857, eight years later The ununited fragments were reduced and nailed Bony union in good position Compare figures 1838—1846

FIG 1858 —Two year old non-union with the head in part decalcified, in part sclerosed Comparatively good circulation of blood

FIG 1858 a —Check roentgenogram re figure 1858, eleven years later Bony union after reduction and nailing Compare figures 1818—1829

FIG 1859 —Three month old non-union of the femoral neck with dense head indicating that the head is not nourished

FIG 1859 a —The femoral head has been removed and replaced by an acrylic head prosthesis

The femoral head must have a good blood supply Optimal local conditions exist if the head shows the same degree of decalcification as the surrounding bones and if the bone ends are sclerosed as in figures 1814, 1815 and 1838 until 1841 Prognosis is also good if only isolated dense foci are visible, as in figures 1820 and 1821 The width of the joint space should be normal A roentgenogram of the whole pelvis should be taken to determine the calcium content of the bones and the width of the joint spaces Moreover, A-P roentgenograms must be taken in external and internal rotation and a lateral view must be made Cases with a dense femoral head and without sclerosed bone ends (figs 1643, 1664) should be excluded as should cases with multiple dense foci (fig 1738) or cases with complete loss of the neck, with or without

upward displacement of the trochanter (figs 1816, 1817) The length of the femoral neck must be at least 35 mm

Time of Operation It can be carried out at any time During the first few months, as a rule, structural changes in the head become clearly visible in unreduced fractures These changes are favorably influenced by reduction and uninterrupted immobilization with the three-flanged nail There is usually little danger then of depression of the head, since patients with decalcified bones walk very cautiously The oldest non-union for which we have operated had existed for 22 years (figs 1866—1869)

Reduction of Fragments We differentiate complete non-union from fibrous union The former is comparatively rare and usually shows a joint mobility in excess of normal In fibrous union, motion is always limited *Accurate reduction of the fragments is indispensable to a good end-result* Anterior angulation and especially varus position must be corrected completely If this is not done, non-union may develop again and total or partial head necrosis may supervene Sometimes it is expedient to create a slight valgus position. Within the first year, reduction is usually successful after a few days of pin or wire traction as described on page 1210 In a case of complete non-union, reduction in such traction will be achieved within 24 hours (figs 1838—1841) The pin should always be driven through the femur and traction should amount to 12—15 Kg In some old cases of fibrous union, varus deformity and anterior angulation can be corrected only partially in spite of traction so strong as to cause diastasis of the hip joint (fig 1822). In these cases the fibrous bands at the site of the pseudarthrosis should be loosened under general anesthesia by very cautious movement of the limb into extreme abduction and internal rotation The decalcified femur may easily break if the movements are carried out too quickly or too vigorously After anesthesia the traction treatment is continued with heavy weights It is advisable to create a slight overcorrection

If reduction is impossible even under anesthesia, a subtrochanteric osteotomy with nail and plate should be performed (fig 1879)

Extra-Articular Nailing If the fragments are correctly reduced, i e, if varus position and anterior angulation are completely eliminated, extra-articular nailing under local anesthesia as described on pages 1257—1278 can be performed After insertion of the nail, the usually wide gap of pseudarthrosis should be abolished by cautious impaction with the broad impactor Because of osteoporosis, the cortical bone may break if a small impactor is used or if the blows are too powerful Should such cortical fracture occur, a trochanteric plate must be attached to the three-flanged nail as in figure 1879

If the fragments cannot be reduced exactly, one should nonetheless refrain from open reduction to avoid further damage to the vessels and the consequent danger of head necrosis Subtrochanteric osteotomy or arthroplasty should be preferred

Treatment of Non-Union of the Femoral Neck with Insertion of a Three-Flanged Nail into the Acetabulum in Cases of Short or Completely Absorbed Femoral Neck (Transfixion) We have carried out this operation in five cases

when, because of absorption of the neck and of part of the head, only a small part of the head, less than 30 mm long, remained The nail was driven 20 mm deep into the acetabulum to transfix the femoral head firmly In the patient shown in figs 1860—1865, bony union without head necrosis was achieved In the other four cases, non-union and head necrosis developed, which was not surprising since absorption of the neck is always a sign of severe circulatory disturbance of the head Therefore we no longer use this method

Treatment of Non-Union of the Femoral Neck with Arthroplasty or Arthrodesis With the femoral head less than 30 mm high or in the case of head necrosis, an arthroplasty with an acrylic or Vitallium head (figs 1565 c, 1733) can be performed if the patient's complaints are severe and his general condition is good Sometimes it is better to do an arthrodesis (figs 1565, 1855)

Questions We Should Ask Ourselves to Avoid Failure When Treating Non-Union of the Femoral Neck

1 Have I accurately examined the patient's general condition?
2 Have I examined the condition of the femoral head with A-P roentgenograms taken with the limb in external and internal rotation, with a lateral roentgenogram and with an A-P scout film of the entire pelvis in order that I be able to recognize circulatory disturbances as accurately as possible?
3 Have I excluded from operation cases with noticeably disturbed blood supply to the head?
4 Have I put the Steinmann pin for traction through the femur rather than through the tibial tubercle in order to exert sufficient traction but avoid excessive traction on the knee joint?
5 Have I used traction weights amounting to at least one-seventh and not just one-tenth of the body weight in order to stretch the contracted soft tissues and to reduce the displacement of the fragments?
6 Have I carefully tried to correct the deformity under general anesthesia if varus position and anterior angulation could not be overcome even in spite of a diastasis in the joint?
7 Have I tried to create a slight valgus position?
8 Have I omitted opening the joint to avoid additional circulatory disturbances, when closed reduction was impossible?
9 Have I placed the three-flanged nail exactly into the center of the head?
10 Have I abolished the gap between the fragments by cautious impaction?
11 Have I attached a trochanteric plate to the three-flanged nail when the osteosynthesis was not stable?
12 Have I performed a subtrochanteric osteotomy when closed reduction was impossible?
13 Have I traced the roentgenogram before doing subtrochanteric osteotomy to determine exactly the necessary width of the wedge to be removed so that the angle between the femoral shaft and the long axis of the head be 135°—140°?



1860, June 25, 1935



1861, July 1, 1935



1862, December 8, 1935



1863, July 1, 1936



1864, November 3, 1937



1865, March 8, 1938

FIG 1860—Non-union of the femoral neck in a 54 year old physician, 14 months after the accident Femoral neck absorbed Dense foci in the head Cranial displacement of the trochanter Shortening of 3 cm Patient was treated *elsewhere* with a plaster cast for $4^1/_2$ months, then weight-bearing splint Walks badly with splint and two crutches Limb swollen, pain in the hip

FIG 1861—Check roentgenogram re figure 1860, after operation Seven days of tibial pin traction with 12 Kg has brought the trochanter down Because the head fragment was so small, the long nail was purposely driven 20 mm into the acetabulum There is a wide gap between the fragments in spite of attempted impaction Patient started walking without cast or splint 14 days later

FIG 1862—Check roentgenogram re figure 1860, six months later The gap between the fragments has disappeared The fragments' approaching each other caused the nail to penetrate deeper into the pelvis A cavity has formed in the acetabulum round the tip of the nail Patient can walk well indoors without a cane and feels no pain

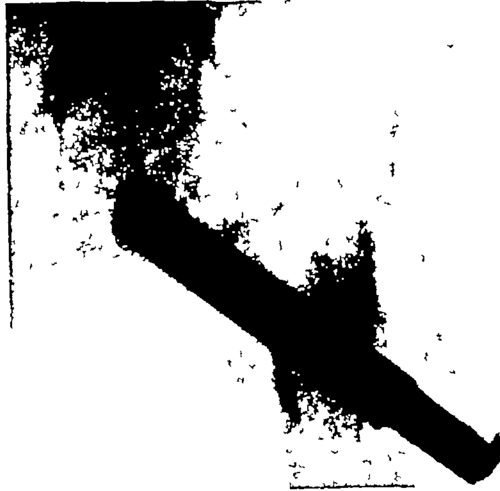
FIG 1863—Check roentgenograms re figure 1860, one year later Bony union of the fragments, with clearly visible bony bridging across the fracture caudal to the nail

FIG 1864—Check roentgenogram re figure 1860, two and a half years later Complete consolidation of the fracture Calcium content of femoral head good Patient can walk without a cane, without pain Hip flexion 180°–150° Free active motion of the other joints

FIG 1865—Check roentgenogram re figure 1860, two years and nine months later, 14 days after removal of the nail Bony consolidation of the fragments We have nailed four other cases with such small head fragments, and all four developed necrosis of the head



1866, June 10, 1936



1867, July 3, 1936



1868



January 24, 1938 1869

FIG 1866—Non-union of the femoral neck in a 50 year old female following a fracture sustained in a fall 22 years previously, i e, when she was 28 Fibrous union, severe cranial displacement of the trochanter Diffuse demineralization Good blood supply to femoral head The lesser trochanter is propped against the head Shortening of 5 cm External rotation is possible through 40° Hip flexion 160°—140° Patient walks with a severe limp and has pain Patient had been treated with adhesive tape traction for six weeks, then electric treatment for 3 years with gymnastics, passive movements and 2—3 hours of massage every other day Course of curative bath treatment every year Several courses of injections

FIG 1867—Check roentgenogram re figure 1866, after operation Tibial and, later on, femoral pin traction with 15 Kg has been exerted for three weeks The trochanter has been pulled down 30 mm Good position of the nail, caudal to the center of the head and neck The cortical bone of the femoral shaft was comminuted when impaction of the fragments was attempted

FIGS 1868, 1869—Check roentgenograms re figures 1866 and 1867, one and a half years later Firm bony union, good calcium content Hip flexion free, abduction one-half of normal Rotation limited by two-thirds Patient walk without pain, without cane and without considerable limp

Arthrotic Changes in the Hip Joint After Nailed Fractures of the Femoral Neck

Causes of Arthrotic Changes They are the consequence of circulatory disturbances of the femoral head They develop to a varying degree in all cases of caput necrosis and non-union of the neck They can also develop without necrosis or non-union if the cartilage disappears because of circulatory disturbance Arthrotic marginal exostoses develop on the acetabulum and the femoral head, motion becomes limited, and painful contractures develop

Time of Occurence and Frequency of Arthrotic Changes in Nailed Fractures of the Femoral Neck Without Depression of the Head According to Ender and Krotschek, they develop in 4 per cent before the end of the third year, in 14—15 per cent after 3—5 years, and in a further 14—15 per cent after 6—8 years Even the smallest arthrotic changes are included, e g, 1 mm -long marginal exostoses Thus about one third of all femoral neck fractures without necrosis develop arthrotic changes

Treatment of Arthrotic Changes Following Fractures of the Femoral Neck When pain occurs, it will cease in light cases after rest in bed, baking, short waves or diathermy In the presence of severe complaints one should consider arthrodesis or arthroplasty

End-Results After Nailed Adduction or Varus Fractures of the Femoral Neck

From May 1933 to May 1948 we carried out extra-articular nailing at the Vienna Accident Hospital in 399 adduction or varus fractures of the femoral neck Ender [1] has followed-up 193 patients for 3—18 years after the operation, viz .

of 302 recent cases	130 (43 3%) follow-up
of 49 delayed cases	27 (55 %) follow-up
of 48 non-union cases	36 (75 %) follow-up
399 nailed cases	193 followed-up cases

These cases were classified as "recent" when they were nailed within the first four weeks, "delayed" when they were nailed in from one to six months, and "non-union" when nailed after six months

Of the 302 recent cases, 18 (5 9%) died, viz

from pulmonary embolism	2
from heart failure	9
from infection	4
from other diseases (apoplexy, hemorrhage from a gastric ulcer, uremia)	3
	18

The two cases of embolism occurred before the patients got up The four cases of infection were in close sequence in 1945

The 130 followed-up recent cases showed the following results 3 to 18 years after operation

[1] Ender Behandlung der intraartikularen Schenkelhalsbruche und ihre Folgen mit Ergebnissen der Nachuntersuchung, Arch f orthop und Unfall-Chir 45 237 253, 1952

Clinically and radiologically satisfactory	72 (55 4%)
Non-union without caput necrosis	4 (3 1%)
Non-union with caput necrosis	5 (3 8%)
Total necrosis without non-union	18 (13 8%)
Partial necrosis	23 (17 6%)
Arthrotic changes	8 (6 2%)

At our first follow-up examination in 1938 we were of the impression that we had no cases of non-union The time of observation had been too short In some cases the non-union can be clearly seen only after 1 to 2 years (figs 1847—1853, 1856 a—f) In non-union without caput necrosis the cause was always unstable osteosynthesis This means that it can be avoided by correct nailing technique



1870 1871 1872 1873
April 15, 1926 January 22, 1926

FIG 1870—Non-union of the femoral neck in a 54 year old female one year after the accident See roentgenogram Vol I/fig 319 Adduction contracture of left hip

FIG 1871—Same patient from behind When the patient stands on the broken *left* lower limb, the *right* side of the pelvis sinks (Trendelenburg sign)

FIG 1872—Check photograph re figure 1870, twelve weeks after subtrochanteric osteotomy See roentgenogram, Vol I/fig 321 The left lower limb can be abducted

FIG 1873—Check photograph re figure 1871, twelve weeks after subtrochanteric osteotomy When the patient stands on the operated limb, the sound side of the pelvis is raised i e, the Trendelenburg sign has disappeared The neck of the femur had united by bone in two years (see Vol I/fig 322)

The 27 followed-up delayed cases yielded the following results after 3 to 18 years

Clinically and radiologically satisfactory	15 (55 6%)
Non-union without caput necrosis	1 (3 7%)
Non-union with caput necrosis	2 (7 4%)
Total necrosis without non-union	4 (14 8%)
Partial necrosis	4 (14 8%)
Arthrotic changes	1 (3 7%)

The 31 followed up non-union cases showed the following results after 3 to 18 years

Clinically and radiologically satisfactory	15 (48 5 %)
Non-union without caput necrosis	2 (6 45%)

Non-union with caput necrosis	2 (6 45%)
Total necrosis without non-union	0 (0 %)
Partial necrosis	6 (19.3 %)
Arthrotic changes	6 (19 3 %)

The relative number of necroses in non-unions treated by ordinary nailing is nearly 50 per cent smaller than in the recent and delayed fractures of the femoral neck

The fact that no total necrosis developed shows that the circulatory factor had been judged correctly before operation

In the four cases of persistent non-union, osteosynthesis was not stable. The six cases of partial necrosis indicate that the selection of cases was not careful enough The arthrotic changes in the six patients were partly caused by the already long-standing non-union The results show that with correct selection of cases and with accurate technique, non-union of the femoral neck can as a rule be healed by ordinary nailing without bone grafting

The five non-unions treated with transfixation, where the head was of a diameter of 30 mm and less, showed the following results 3 to 18 years later

Clinically and radiologically satisfactory	1 (20%)
Non-union without caput necrosis	1 (20%)
Non-union with caput necrosis	3 (60%)
Total necrosis without non-union	0 (0%)
Partial necrosis	0 (0%)

The results show that transfixion should not be carried out in a small femoral head of a diameter of less than 30 mm , since marked absorption of the central fragment is in itself an indication of absent or impaired blood supply to the head

Of our cases of recent and delayed nailing of fractures of the femoral neck, 55 per cent are clinically and radiologically normal (figs 1726, 1727, 1736) Of the 17 per cent partial necroses (figs. 1737, 1836, 1837), many had no considerable complaints, so that about 70 per cent could use their limb well. With good selection of the cases, gentle reduction, use of rust-proof nails and correct technique of nailing creating a stable osteosynthesis, 85 per cent can be healed well Thus there is no reason for removing the femoral head and replacing it by an artificial one in recent fractures of the neck, in well-selected delayed cases, and in non-union without circulatory disturbances of the head.

56. FEMORAL NECK FRACTURES IN JUVENILES

Origin. Fractures of the femoral neck in juveniles are caused as in adults by falls on the hip or by quick turns (see page 1161) Whereas this fracture is very frequent in old age, it seldom occurs in juveniles Our youngest patient was eight years old, it has been observed even in a 5 year old patient When there has been long delay between injury and reporting for care of that injury, one cannot always rely on the report of the relatives (fig 1878)

Site of the Fracture. The fracture usually lies near the base of the femoral neck (figs 1874—1893), where in adults mostly pathological fractures occur

Types of Fracture and Displacement of the Fragments Usually the fracture line runs transversely to the long axis of the neck Fissure fractures without displacement are comparatively frequent (figs 1874, 1892) With displacement, we have so far seen only *adduction or varus fractures* (figs 1877—1886) We have never seen *abduction or valgus fractures* in juveniles

Complications Following Femoral Neck Fractures in Juveniles As in adults, also in juveniles, necrosis of the femoral head may develop (figs 1888 through 1891, 1894—1897) Non-union of the femoral neck (fig 1878) has been seen, as have severe angulation and shortening (fig 1885) unusual in adults

Necrosis of the femoral head (figs 1886—1887) in juveniles is usually total The femoral head is re-vascularized later on either partially or completely and thereby revived If weight-bearing is prevented in time, only small depressions will occur (figs 1889—1891) Otherwise complete crushing with absorption of the head will follow, as will prominent marginal exostoses (figs 1894—1897) It is perplexing to find total necrosis developing even after simple fissures (figs 1892—1897)

Non-unions (fig 1878) are always fibrous unions with coxa vara The femoral head does not become necrotic

Severe angulation and shortening with upward displacement of the trochanter develop because of insufficient reduction or too short immobilization in cases of delayed union with partial absorption of the neck (figs 1880—1885) Except for the "gap" of non-union, no difference in shape is seen between the pseudarthrosis of figure 1878 and the coxa vara of figure 1885

Clinical Examination in Suspected Fracture of the Femoral Neck in Juveniles. It is carried out in the same way as in adults (see page 1162)

The *recognition* is comparatively easy if the patient could no longer walk after the accident, if the limb lies in external rotation, if the hip region is tender and if pain in the hip can be elicited by traction, impaction and rotation of the limb If the patient continued walking, as in figure 1874, or if weight-bearing became impossible as late as the next day, as in figure 1892, a fissure can easily be overlooked Sometimes pain on rotation is the only clinical sign

X-ray examination as described on page 1164 must follow the clinical examination

This fracture will not be overlooked if the questions enumerated on page 1164 are considered at examination

Treatment. In the case of displacement, *reduction* is best carried out by continuous traction (see page 1209) Reduction can also be done under local anesthesia by abduction, longitudinal traction and internal rotation Reduction is usually easy

Immobilization may be effected by —

1 Continuous traction (see page 1209 and figure 1604 a—d);
2 Thoracopelvic hip spica (see pages 1214—1228 and figures 1626—1642), or
3 Osteosynthesis (nail and plate, see pages 1256, 1332 and figures 1879, 1980 c, 2130)



1880, October 12, 1928



1881, October 17 1928



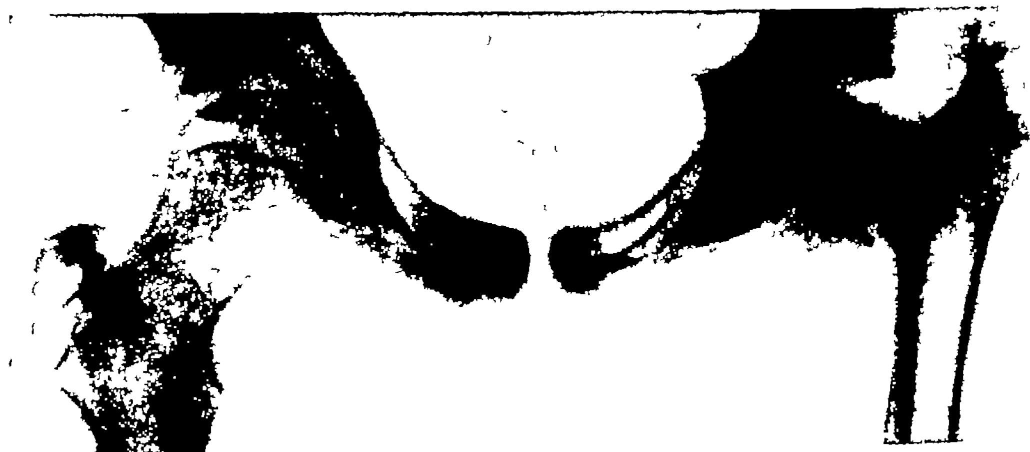
1882, January 26, 1929



1883, March 17, 1927



1884, April 27, 1929

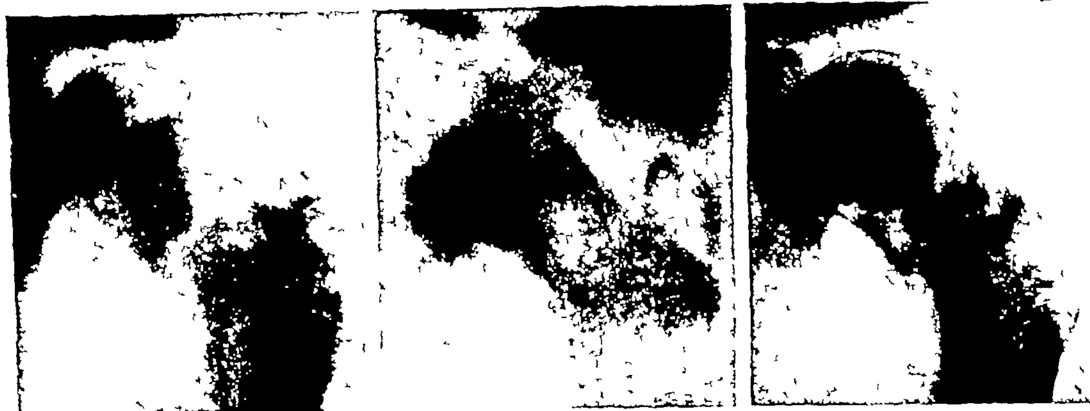


1885, October 22, 1932

FIG 1880 Lateral fracture of the femoral neck in a 9 year old boy, resulting from a fall Marked external rotation and coxa vara of 105° The femoral neck appears shortened by nearly half because of the marked antecurvature

FIG 1881 Check roentgenogram re figure 1880, after reduction and with the patient in plaster cast Ideal position of the fragments, limb in full internal rotation Coxa vara has disappeared Treated *elsewhere*

FIG 1882 Check roentgenogram re figures 1880 and 1881, three and a half months later The plaster cast was removed after six weeks Then massage, passive movements and electric treatments Coxa vara 100° Wide fracture gap Normal calcium content Two thirds of the neck has been absorbed



1886, January 8, 1934 1887, January 12, 1934 1888, March 20, 1934



1889, July 15, 1935 1890, January 5, 1936 1891, June 28, 1936

Fig 1883—Check roentgenograms re figure 1880, five months later Coxa vara of 90°

Fig 1884—Check roentgenogram re figure 1880, six and a half months later Coxa vara of 80° The fracture gap is partly bridged by bone

Fig 1885—Check roentgenogram re figure 1880, four years later Coxa vara of 80° Bony union Severe shortening of the neck, normal calcium content, epiphyseal line partly visible Shortening 4 cm, and patient walks with severe limp In this case pertrochanteric osteotomy with nail and plate as in figure 1879 would have been advisable

Fig 1886—Lateral fracture of the femoral neck in a 10 year old boy who fell when skating Slight lateral displacement, no considerable angulation

Fig 1887—Check roentgenogram re figure 1886, after reduction and with the patient in plaster Good position of fragments The plaster cast was removed after seven weeks, i e, too early

Fig 1888—Check roentgenogram re figure 1886, two and a half months later Good periosteal callus Fracture gap not yet bridged by bone Normal form of femoral head, but it is dense a sign of total necrosis Pain on walking Mobility severely limited In this condition a weight-bearing plaster cast should be applied as shown in figures 1581 and 1582 to avoid depression of the head

Fig 1889—Check roentgenogram re figure 1886, one and a half years later Fracture united by bone Femoral neck shortened by half Depression of the head, it shows irregular structure

Fig 1890—Check roentgenogram re figure 1886, two years later The head has been further flattened and is dense There is a sequestrum in the cranial part of the head

Fig 1891—Check roentgenogram re figure 1886, two and a half years later The flattening of the femoral head has again slightly increased The sequestrum has healed in Joint space again regular

In osteosynthesis the nail must not penetrate the epiphyseal line if the danger of disturbed growth is to be avoided

Time of Immobilization Fractures without displacement are treated in continuous traction or the thoracopelvic hip spica for at least 9—10 weeks

Fracture with displacement must be immobilized in continuous traction or a thoracopelvic hip spica for at least 14 to 16 weeks until definite bony union has occurred If the plaster cast is removed as early as after seven weeks (fig 1881) reangulation will develop (fig 1882) and then absorption of the femoral neck After osteosynthesis, nail and plate are left in place permanently if they cause no trouble

If the femoral head is dense and the fracture not yet united, as in figure 1888, continuous traction must be prolonged until bony union has occurred If the femoral head is then still dense, a weight-bearing plaster cast is applied (figs 1581, 1582) or the patient is given crutches which he must use until the head is revascularized This may take one to two years

Those who fear stiffening of the hip joint by long immobilization should remember, as is stated on Vol I/p 77, that permanent restriction of motion never occurs in a juvenile joint that has not been previously damaged by injury or disease There is no sense in early removal of an immobilizing cast to allow massage and passive movements If the cast is removed too early, caput necrosis, non-union and angulation may develop *causing* the limited motion which was supposed to have been prevented by massage and passive movements

Weight-bearing in the Whitman spica or after osteosynthesis can be allowed after three to four weeks if roentgenograms show that the femoral head is not abnormally dense

X-ray Checks During the period of immobilization, check roentgenograms should be made every four weeks to see whether the position of the fragments is good and whether the femoral head is becoming dense After discontinuance of immobilization, A-P roentgenograms in external and internal rotation and lateral views are made every three months In case of doubt, a survey film of the whole pelvis should be made to allow comparison of the two sides relative to position and calcium content

Keeping Juvenile Femoral Neck Fracture Cases Under Observation To avoid possibly severe crushing of the head and arthrotic changes as shown in figures 1894—1897, the patients must be told to report for examination at once if any pain develops in the hip Otherwise they may fall into the hands of masseurs who try to improve joint mobility by means of forceful passive motion Or they may perhaps be subjected to treatment with lamps emitting light of one color or another, or with injections. Then the correct measure — i e , relief from weight-bearing — may come too late

If these patients are carefully followed and are reviewed clinically and radiologically every three months, incipient changes in the femoral head can be detected and weight-bearing can be stopped before the head becomes crushed

Treatment of Caput Necrosis If the head becomes disintegrated in a way similar to that in Legg-Calvé-Perthes' disease (fig 1889), weight-bearing should

be omitted to avoid crushing of the head before it has revascularized, as in figure 1891 If the femoral head collapses and pain develops in the joint, as in the case shown in figures 1894 and 1895, it is best to do an arthrodesis in good position as shown in figures 1565 e, 1855 and 1899 This affords permanent freedom from pain, whereas pain often persists after arthroplasty

Treatment of Non-Union and Coxa Vara In both conditions a transverse subtrochanteric wedge osteotomy with nail and plate should be performed as described on page 1332 and shown in figures 1879 and 2130 With the direction of the stress shifted, the pseudarthrosis will be bridged with bone within a few months Limping will cease, since the gluteal muscles are lengthened and tensed by the downward displacement of the greater trochanter (Vol I/figs 318 and 1928) The shortening is diminished by 3 to 4 cm

Disability Assessment If necrosis of the head develops in a juvenile patient one or two years after a fall on the hip after which a fissure is seen clearly in the roentgenogram (figs 1892, 1893), it must be recognized as a consequence of the accident If walking was impossible for 3 to 4 weeks after a fall on the hip and if no roentgenogram was made during that time, one must keep in mind that should a caput necrosis develop one to two years later it may well be the consequence of a fissure resulting from that fall

Questions We Should Ask Ourselves to Avoid Failures When Examining and Treating Femoral Neck Fractures in Juveniles

1 Have I, in a suspected fracture of the femoral neck, specifically determined whether pain can be elicited by rotation of the limb with hip and knee flexed?

2 Have I, in a suspected femoral neck fracture, made A-P roentgenograms with the limb in external and internal rotation and a lateral view as well?

3 Have I, when using the thoraco-pelvic hip spica, applied the cast with the limb in extreme abduction, and does the cast extend from the axillae to the tips of the toes?

4 Have I applied the thoracopelvic hip spica with the limb in internal rotation?

5 Have I seen to it that in osteosynthesis the nail does not penetrate the epiphyseal line?

6 Has weight-bearing been omitted during the first four weeks in plaster or after osteosynthesis?

7 Have I immobilized fractures *without* displacement for at least 9 to 10 weeks and fractures *with* displacement at least 12—16 weeks until the roentgenograms show definite bony union?

8 Have I kept juvenile patients with femoral neck fractures under careful observation and made appointments every three months for clinical and X-ray examination in order to detect late cases of caput necrosis in time?

9 Have I recognized late caput necrosis developing after simple fissure fracture (figs 1892—1897) as a consequence of the injury?



1892, July 2, 1928



1893, July 23, 1928



1894, July 14, 1930



1895, September 9, 1931

FIG 1892—Fine fissure fracture through the base of the femoral neck in a 15 year old blacksmith's apprentice who fell from a height of 6 feet Patient could walk, but with pain On the next day, weight bearing was impossible Pain ceased when tibial pin traction was applied Traction was removed after 18 days, i e, too early

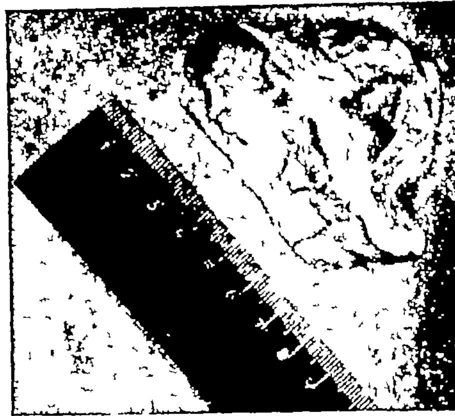
FIG 1893—Check roentgenogram re figure 1892, three weeks later Slight periosteal callus is seen at the medial side of the fracture line Walks without complaints Joint freely mobile Resumed work 25 days after injury

FIG 1894—Check roentgenogram re figure 1892, two years later After one year without complaints, the patient noted the onset of dragging pain which slowly increased A necrosis of the head is seen about as in figure 1669, with a 5 × 2 cm depression cranially and a large marginal exostosis dorsocaudally

FIG 1895—Check roentgenogram re figure 1892, three years later The necrosis of the head is now sharply limited Depression and marginal exostosis have increased in size Severe pain on walking



1896, March 17, 1933



1897, March 17, 1933



1898, May 15, 1933



1899, May 30, 1937

Fig 1896—Check roentgenogram re figure 1892, five years later The necrotic part of the femoral head has been almost completely absorbed The femoral neck has revived and shows almost normal calcium content The marginal exostosis has become still larger Hip flexion 150^0—90^0 Abduction and rotation nil Severe pain on walking, but patient can walk for 15 minutes

Fig 1897—Photograph of the excised femoral head It is irregular and cracked, and the greater part of the cartilage is destroyed It is surrounded by a large marginal exostosis of 8 cm diameter

Fig 1898—Check roentgenogram re figure 1896, after excision of the femoral head The femoral neck was put into the acetabulum and the greater trochanter was moved caudally It was shifted *too far* caudally and was fixed with two stainless steel nails

Fig 1899—Check roentgenogram re figure 1892, $9^1/_2$ years later and 4 years after the attempted hip arthroplasty Bony ankylosis Limb slightly abducted, so that there is no shortening Patient walks and stands without pain

57. SEPARATION OF THE PROXIMAL FEMORAL EPIPHYSIS

Origin. Whereas separation of the epiphyses in other parts of the skeleton — e g, at the distal end of the femur, both ends of the tibia, humerus, and radius — is the result of severe trauma, separation of the proximal femoral epiphysis is usually attributed to such trivial causes as slipping, carrying a sack (figs 1900, 1901), pushing a cart (figs. 1916, 1917) or ordinary walking (figs 1921, 1922) When the matter is investigated it is usually found that weeks or even months before such minor injury, pain had been felt in the hip, thigh and knee We have come across several cases in which pain referred



1900



1901

FIG 1900—Separation of the left proximal femoral epiphysis in a 16 year old cook's apprentice who fell when carrying a sack of sugar He felt pain in the hip for several weeks The femoral head has slipped caudally one-third of its width Compare with photograph in figure 1904

FIG 1901—Comparison roentgenogram re figure 1900, taken in lithotomy position The head has slipped dorsally by half its width Dorsally open angle between head and neck with angulation of 50° The changes along the ventral side of the neck are more clearly seen in the lateral view than in the anteroposterior view

to the knee caused the region of the knee to be treated for a long time (figs 1902, 1903) because examination of the hip had been omitted

Age and Sex Incidence Separation of the proximal femoral epiphysis generally occurs only between the ages of ten and sixteen years, much more frequently in boys It is found in girls only rarely

Side of Injury Usually the left leg is diseased, probably because it is submitted to greater stresses in right-handers We have had only one case of bilateral separation, though others have reported 15—30 per cent of their cases to have been bilateral

Anatomic Changes Separation of the proximal femoral epiphysis always takes place in the epiphyseal line itself, whereas in traumatic epiphysial separation at the lower end of the femur and other bones a bone wedge of varying size is usually broken off from the metaphysis (figs 748, 749, 785, 786, 2061, 2062, 2489, 2490) The cranioventral end of the femoral neck is



1902



1903

Fig 1902—Separation of the left proximal femoral epiphysis in a 15 year old confectioner's apprentice sustained by slipping He felt pain for six months in his left lower limb referred to the knee The knee was therefore treated elsewhere with short-wave diathermy and ultraviolet light Much smaller displacement of the femoral neck than in figure 1900

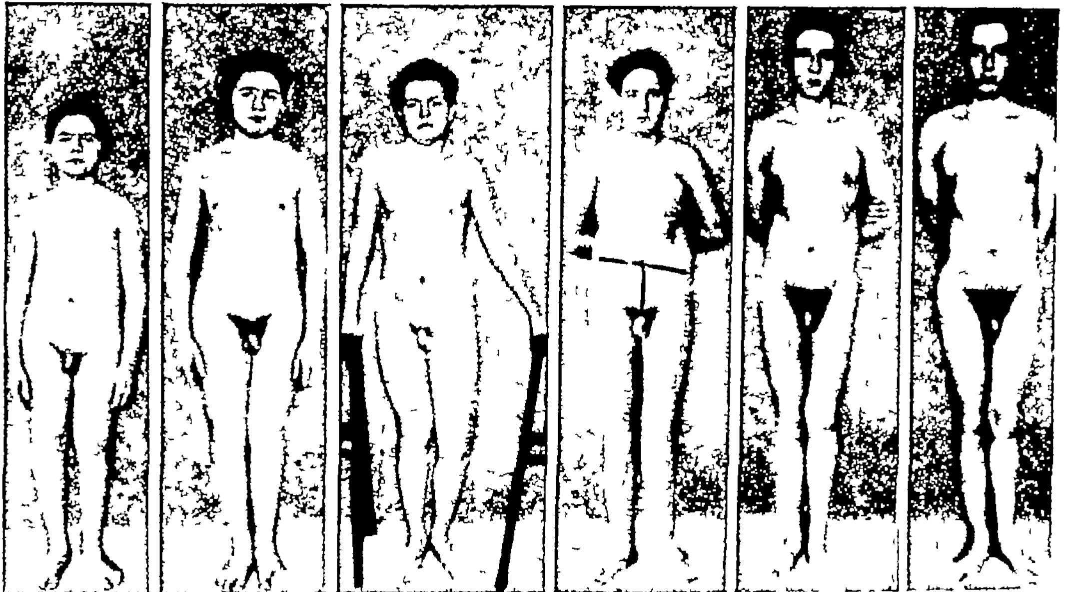
Fig 1903—Comparison roentgenogram re figure 1902, in lithotomy position The femoral head has slipped dorsally by one-third of its width Compare with photographs in figures 1906, 1914 and 1915 Much milder changes than in figures 1900 and 1901

usually (figs 1900, 1901) but not always (figs 1916, 1917) strangely rarefied and is sometimes to a great extent absorbed (figs 1939—1942)

Displacements of Fragments Displacement is more marked in the lateral than in the anteroposterior roentgenogram In a normal anteroposterior roentgenogram the epiphysis lies slightly oblique to the long axis of the femur,

forming an angle of 20°—30° (figs 1900, 1902) With a slipped epiphysis that angulation is increased, e g, 55° in figure 1902 and 80° in figure 1900 In the lateral view the epiphyseal line normally makes a right angle with the femoral neck If the epiphysis slips dorsally this angle is decreased It is only 40° in figures 1903 and 1917 and only 15°—20° in figures 1901 and 1922 Thus there is coxa antecurvata and vara, but displacement in the sense of antecurvature always exceeds that in the sense of varus

Endocrine Disturbances These patients are usually fat and have underdeveloped sexual characteristics (dystrophia adiposogenitalis) The margin of the pubic hair in these boys does not extend upwards to the umbilicus but has a sharp transverse limit (figs 1904—1909, 1931—1936) Their complexion



January 18, 1936 — January 29, 1938 — December 17, 1937 — September 2, 1929 — May 8, 1932 — January 25, 1938

1904—1909

Three apprentices with separation of the proximal femoral epiphysis due to endocrine disturbance All are feminine types, unusually fat with underdeveloped male sexual characteristics Big breasts Transverse upper limit of the pubic hair No hair on abdomen, chest or in the axillae

Fig 1904—A 16 year old cook's apprentice Compare with roentgenograms in figures 1900 and 1901

Fig 1905—Comparison picture re figure 1904, two years later Sexual characteristics better developed

Fig 1906—A 15 year old confectioner's apprentice Compare with figures 1902, 1903 and 1914, 1915 Strikingly little pubic hair, girlish face

Fig 1907—A 16 year old baker's apprentice Compare with figures 1937—1950, roentgenograms and photographs

Fig 1908—Comparison photograph re figure 1907, three years later

Fig 1909—Comparison photograph re figure 1907, nine years later Has grown tall The fat has disappeared, the muscles are strong, the penis is well developed, the testes are comparatively small No hair on chest and abdomen

often resembles that of a girl In the case of the boy shown in figures 1906, 1914 and 1915 we were asked by laymen how a girl could be allowed in a male ward in our hospital Roentgenograms of the skull often show enlargement of the sella turcica, an evidence of enlargement of the pituitary

Separation of the proximal femoral epiphysis seems, therefore, in most cases to be an evidence of endocrine disturbance and not the result of a serious accident

In this condition the disease begins first in the epiphyseal disc itself, in contrast to osteochondritis dissecans (Perthes-Legg-Calvé) in which the surface of the head and often the upper part of the acetabulum are diseased while the epiphyseal disc shows no change In assessing disability it is important to know that there seem to be cases of separation of the proximal femoral epiphysis due to severe accidents without any previous complaints and in the absence of any discovered endocrine disturbances

Recognition If, without any trauma, a boy of the described type complains of pain in the knee, or if he begins limping after a minor accident, one must think of a possible separation of the proximal femoral epiphysis Then examination must not be limited to the knee alone but must include the hip as well Careful examination with the knee and hip in flexion will reveal minimal limitation of hip motion, particularly in the sense of internal rotation, and pain on rotation In advanced cases the hip joint is definitely painful and mobility is clearly restricted The leg is externally rotated, slightly flexed, and in the beginning sometimes abducted (figs 1900, 1902, 1921, 1937) Later, an adduction contracture develops (figs 1928, 1931, 1951, 1953 and 1954) similar to what may be seen in an infectious condition, e g, tuberculous coxitis To exclude the possibility that one is dealing with infection, the blood sedimentation rate should be determined

X-Ray Examination Separation of the proximal femoral epiphysis can only be confirmed by good roentgenograms It is always necessary to take anteroposterior views in external and internal rotation as well as lateral views Roentgenograms should be made not only of the diseased side but also of the sound side for comparison, i e, a survey film of the whole pelvis should be made (figs 1900, 1902) It is best to make the lateral roentgenograms with the patient in the lithotomy position (figs 1901, 1903) If this is not possible, a lateral view of the extended hip is made as in figures 1702 and 1703 In this case, a single film affording comparison with the sound side in lateral projection is impossible If adequate roentgenograms are not made, beginning changes as in figure 1902 can easily be overlooked Only by comparison with the sound side can they be seen clearly, and the lateral view (fig 1903) will often show the epiphyseal displacement even to the less experienced Changes visible in the anteroposterior view are often taken for infectious foci and treated as such The postreduction films will prove this assumption to have been wrong (fig 1938)

Possible Complications Following Separation of the Proximal Femoral Epiphysis If the condition is not recognized and treated in time, considerable displacement, deformity, limitation of motion and stiffening of the hip will

follow, as shown in figures 1931, 1932 and 1953—1958 Absorption of the femoral neck (figs 1939—1944) may follow, or caput necrosis (figs 1924 a—c), or loss of the joint cartilage (figs 1951, 1952)

Treatment of Beginning Separation of the Proximal Femoral Epiphysis with Pins Drilled Through the Skin or with the Three-Flanged Nail

If beginning separation of the epiphysis is recognized in time and an infectious disease can be excluded, further slipping of the epiphysis can be avoided by percutaneous insertion of four or five stainless wires They should have a diameter of 2 to 2 5 mm , should penetrate the epiphyseal plate and should approach the joint surface closely



1910



1911

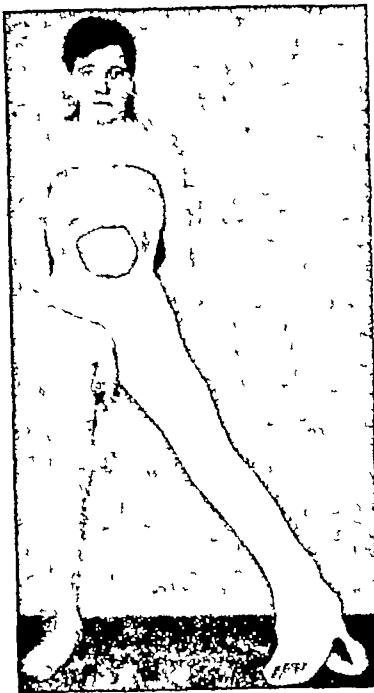
Fig 1910—Separation of the proximal femoral epiphysis Same case as figures 1900, 1901 and 1904, 1905

Fig 1911—Check roentgenogram re figure 1910, after tibial pin traction for two days The femoral head has been pulled 1 cm out of the acetabulum, but the displacement between head and neck has not been changed

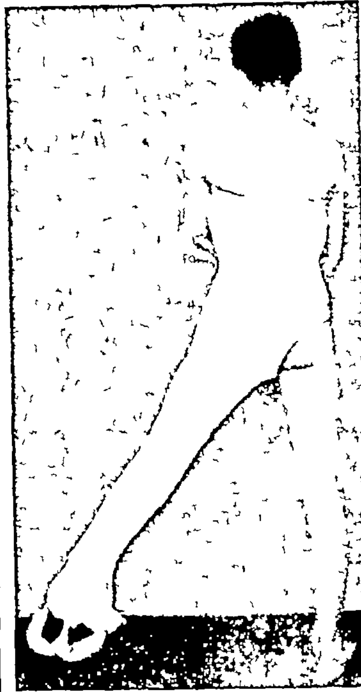
For insertion of the wires the patient is placed on the extension table as for femoral neck nailing (figs 1701—1703) Anteroposterior and lateral roentgenograms are made with the wire grid and the water-level to locate the femoral neck axis (figs 1710—1712) Then the first wire is drilled in and new roentgenograms are made in the same two planes If the wire is placed well, three or four more wires are inserted parallel with it or slightly oblique to it. If roentgenograms then show that the wires have not been drilled in deep enough, they are driven in deeper If they have pierced the articular cortex of the head they are pulled back If new roentgenograms in both planes show that all wires are placed well, the wires are snipped off subcutaneously

The patient is allowed up bearing weight one week later

Removal of the wires They must be left in place until the epiphyseal line has fused If they are removed too early there is the danger of re-displacement



1912



1913



1914



1915

Figs 1912, 1913 —Plaster cast used in separation of the proximal femoral epiphysis partly caused by trauma Strong abduction and moderate internal rotation The cast has not been cut out sufficiently about the buttocks No obesity Normal genitalia Compare with roentgenograms in figures 1916—1920

Figs 1914, 1915 —Plaster cast for separation of the proximal femoral epiphysis caused by endocrine disturbance Strong abduction and extreme internal rotation A second walking caliper has been applied medially to prevent slipping on the floor Abdominal window slightly too big Compare with roentgenograms in figures 1902, 1903 and photograph in figure 1906

Instead of the wires drilled in through the skin, a three-flanged nail can be inserted as in a medial fracture of the femoral neck (see pages 1257—1278). Walking can be allowed two weeks later The nail can be left in place permanently if it causes no trouble





1916 February 27, 1936 1917





1918 July 17, 1936 1919

FIGS 1916, 1917—Separation of left proximal femoral epiphysis in a 16 year old coppersmith's apprentice Four weeks previously a heavy copper tube fell against his thigh After that he had slight pain in the hip but did not stop working until he suddenly collapsed with severe pain in the hip when he pushed a cart on the road In contrast to findings in figures 1900 and 1901, the femoral neck shows no abnormality

FIGS 1918, 1919—Check roentgenogram re figures 1916 and 1917, five and one-half months later Reduction has been achieved by longitudinal traction, strong internal rotation and abduction Plaster cast for three months Compare figures 1912, 1913 As an exception, patient is of masculine type Healing in good position Fusion is beginning across the epiphyseal line November 29, 1937

Treatment of Recent, Severe Displacement of the Upper Femoral Epiphysis with Percutaneous Wires or with a Three-Flanged Nail

If after slight complaints or without previous complaints the epiphysis suddenly slips so that the patient's limb is externally rotated, so that he feels

severe pain and is unable to walk, reduction should be attempted within the first few days If the displacement has existed for more than one week, however, one should refrain from manipulation, as this sometimes leads to circulatory disturbances of the femoral head

Reduction By Manipulation. The patient is placed on a screw traction apparatus (fig 1701) Under general anesthesia or with local anesthesia of the hip joint, the knee is flexed to a right angle Both limbs are cautiously abducted under slight longitudinal traction and without great force, and they are internally rotated These movements must not be overdone lest they cause over-correction The position is checked by anteroposterior and lateral roentgenograms If reduction is not yet complete, it can be made so by increased abduction and internal rotation Overcorrection, on the other hand, is very difficult to eliminate



FIG 1920—Check roentgenogram re figures 1916 and 1917, one and a half years later Femoral neck slightly broader than on sound side Lateral to the former epiphyseal line a marginal exostosis projects from the cranial side of the femoral neck, since the epiphysis has slipped slightly again Hip flexion 180°–135°, abduction and rotation limited by half He can walk for 2 to 3 hours, but limps slightly Patient feels some pain in the hip on overexertion and with change in the weather

Reduction through continuous traction is said to be possible in some cases within the first few days In general, all that is effected by traction is distraction of the joint (fig 1911) without any change in the existing displacement

Immobilization with percutaneous wires is carried out as described on page 1356

For immobilization with the three-flanged nail the patient is operated on as for a medial fracture of the femoral neck (pages 1257—1278)

When Are the Patients Allowed Up? Contrary to the situation with beginning separation of the proximal femoral epiphysis, where weight-bearing is allowed as early as eight days after percutaneous wire fixation or 15 days after nailing, patients suffering from severe epiphyseal displacement are allowed up only after three weeks and even then should not bear weight on the limb but should use crutches without touching the foot to the ground

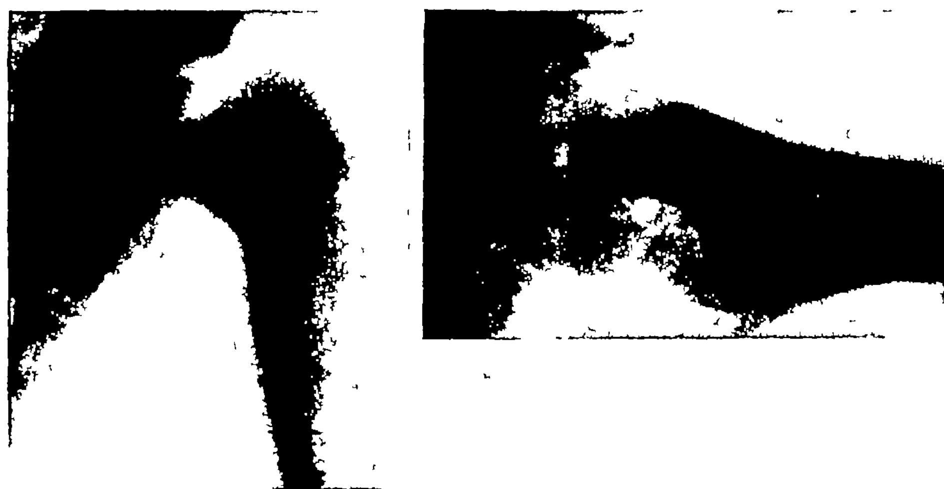
When Should Weight-Bearing Be Allowed? It should be allowed only after three months if the A-P roentgenograms with the limb in external and inter-

nal rotation and the lateral view show good position and no circulatory disturbance of the head

Removal of the wires should be done only after fusion of the epiphyseal line, to avoid the danger of redisplacement

Removal of the Three-Flanged Nail If it causes no disturbance it may be left permanently On no account should it be removed before fusion of the epiphysis and metaphysis

End-Results in Cases Treated with the Three-Flanged Nail We have seen two cases of caput necrosis (figs 1921—1924 c). In our opinion these were not due to the use and presence of the three-flanged nail but rather to delayed reduction Reduction was performed after 10 days in one case and only after four months in the other



1921 May 3, 1937 1922

FIGS 1921, 1922—Separation of the left proximal femoral epiphysis in a 12 year old, extraordinarily tall boy Three weeks before, after a fall on the road, he felt slight pain in the left hip but could continue walking His limp increased Two weeks later, during an ordinary walk, he suddenly felt a severe pain and could no longer walk Severe external rotation of the limb The ventral corner of the femoral neck seems to be missing

Treatment of Recent, Severe Displacement of the Proximal Femoral Epiphysis with a Bone Graft

Instead of the wires or the three-flanged nail, some surgeons recommend using an autogenous tibial or fibular graft of sufficient size and strength, or a graft from the bone bank The operation is performed in essentially the same way as the nailing in a medial fracture of the femoral neck (see pages 1257—1278) The use of a tibial graft is indicated especially in cases with absorption of the femoral neck as in figure 1939

Immobilization After operation a thoracopelvic plaster hip spica must be applied as described on pages 1214—1228, but without internal rotation and without any considerable abduction

Period of Rest in Bed The patient is kept in bed in the plaster cast for three months

Beginning Weight-Bearing If the epiphysis and metaphysis have fused by the time the plaster cast is removed, weight-bearing may then be allowed. If they have not fused, crutches must be used until fusion occurs

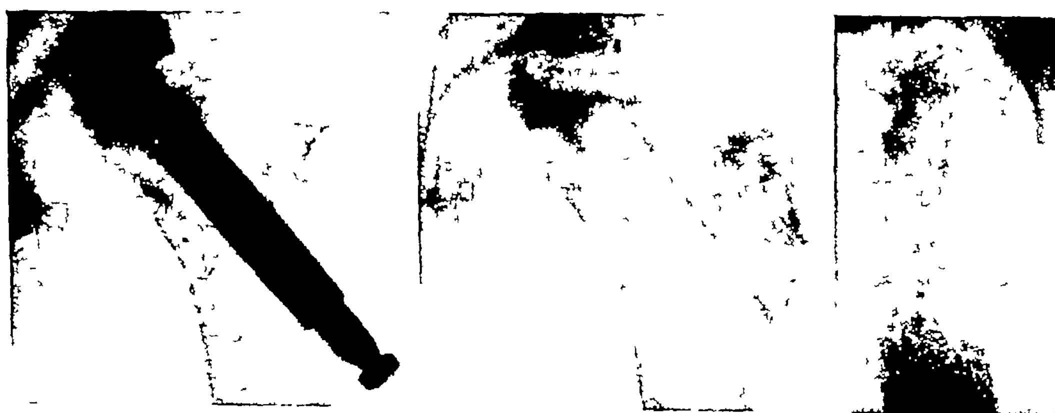
Treatment of Recent, Severe Displacement of the Proximal Femoral Epiphysis with the Thoracopelvic Plaster Hip Spica

Formerly we generally used the big Whitman spica for treatment of this type of slipped epiphysis At present we use it in exceptional cases only



1923 May 25, 1937 1924

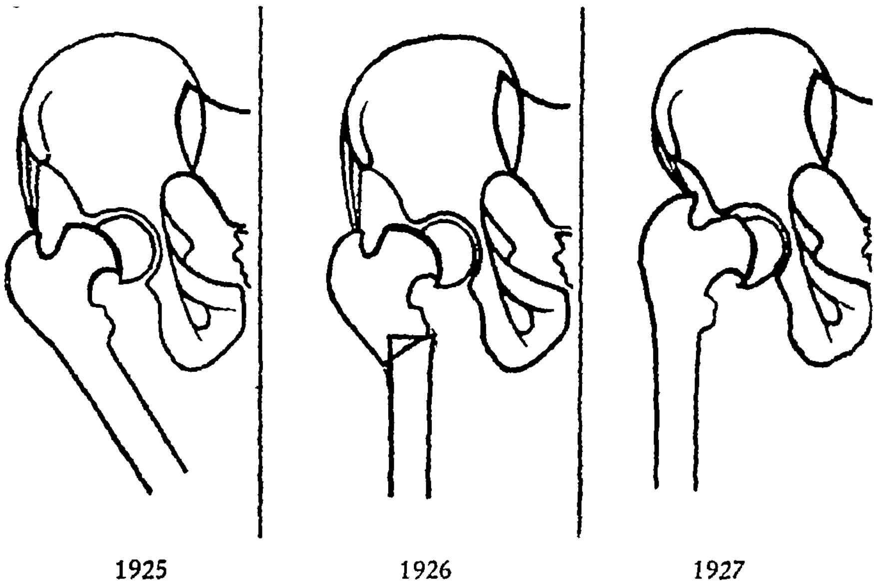
Figs 1923, 1924—Check roentgenogram re figures 1921 and 1922, two weeks after reduction and nailing, which was carried out 10 days after separation of the epiphysis The fragments are well reduced The nail is placed very well in the anteroposterior roentgenogram but slightly too far ventrally in the lateral view He can walk with one stick The joint was freely mobile in all directions nine months later Still slight dragging pain when walking long distances One year later, increasing pain and roentgen evidence of beginning caput necrosis



1924 a, November 7, 1938 1924 b November 25, 1938 1924 c

Fig 1924 a—Check roentgenogram re figure 1921, 1½ years later Necrosis with complete collapse of the femoral head before removal of the nail

Figs 1924 b, c—Check roentgenograms re figures 1921 and 1922, 1½ years later After removal of the nail, the concave part of the head abuts against the lateral edge of the acetabulum, as in figures 1672 and 1673, so that a new joint is formed



1925 1926 1927

Sketched on August 12, 1918

Fig 1925—Marked adduction contracture after slipping of the epiphysis of femoral head Traumatic coxa vara Compare figures 1928, 1931

Fig 1926—Osteotomy just caudal to the lesser trochanter has restored the normal angle between the shaft and the head The length of the gluteal muscles has been restored Compare figures 1929, 1930

Fig 1927—By forced abduction of the adducted limb under anesthesia, the adduction contracture has been overcome But the head of the femur has been rotated out of the acetabulum on the caudal side and its articular cartilage destroyed The vessels of the ligamentum teres are compressed Glutei much shortened Caput necrosis and bony ankylosis often follow this operation



1928, July 6, 1924 1929, July 3, 1924

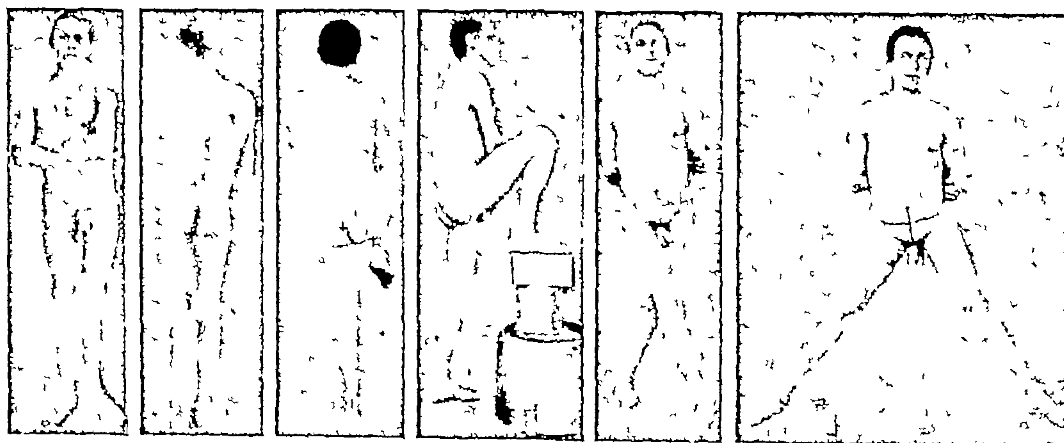
Fig 1928 Slipped epiphysis, two years after the accident Coxa vara with marked adduction Compare with figures 1925, 1931 and 1932

FIG 1929—Check roentgenogram re figure 1928, four weeks after a subtrochanteric osteotomy between two stainless steel pins If traction is used, these can be left in place until bony union has occurred so as to prevent displacement of the fragments If a plaster cast is applied, they are best removed when the cast has set so as to avoid the formation of discharging sinuses To correct the position we now do either a V-shaped osteotomy in a coronal plane or a wedge osteotomy with lateral base, rotate the leg internally and fix the whole with nail and plate as in figure 1879



1930, May 12, 1951

FIG 1930—Check roentgenogram re figure 1928, 27 years later Normal angle between femoral head and shaft Flexion and extension of hip free, abduction and rotation limited by 1/4 No complaints As a peasant living in the high mountains he can do every kind of work without pain



1931, 1932, July 6, 1924 1933—1936, October 10, 1924

FIG 1931, 1932—Marked shortening and external rotation of the left lower limb caused by coxa vara resulting from a slipped epiphysis of two years' standing and marked adduction contracture The heel cannot touch the ground Whole limb has wasted (Figure 1928 shows the roentgenogram)

FIGS 1933—1936—Three months after a subtrochanteric osteotomy followed by continuous traction for nine weeks Abduction limited by 1/4 Trendelenburg's sign negative Flexion of hip free, and the affected limb can be crossed behind the sound one This is only possible with hyperextension of the hip Patient can work hard without complaints 27 years later

Reduction is carried out within the first few days as described on page 1359 After eight days, reduction should as a rule not be attempted



1937, January 3, 1929 — 1938, January 3, 1939

FIG 1937—Slipped proximal epiphysis of left femur in the 16 year old baker's apprentice shown in figure 1907, who slipped on the road He could no longer walk and had to be carried home Three weeks previously he had fallen from a bicycle onto his left hip, and after that he had limped and suffered pain Did not stop working and was treated by his physician with embrocation Dorsal displacement of epiphysis External rotation and abduction of the limb

FIG 1938—Check roentgenogram re figure 1937, after reduction under general anesthesia Angulation, shortening, lateral displacement and rotation have been corrected Nothing abnormal detected in this picture Plaster cast with limb in slight internal rotation for nine weeks



1939, May 4, 1929 — 1940, September 27, 1929

FIG 1939 Check roentgenogram re figures 1937 and 1938, four months later As the roentgenogram after removal of the cast showed considerable displacement, an Unna's paste traction bandage was applied for 16 weeks The position has improved However, a large portion of the femoral neck has disappeared

FIG 1940 Check roentgenogram re figure 1937, nine months later The whole of the femoral neck has been absorbed with the exception of the calcar femorale, which is propped against the acetabular roof Caudal redisplacement of the epiphysis Marked limp



1941, October 5, 1929 1942, March 12, 1930

FIG 1941 — Check roentgenogram re figure 1940 after osteotomy between two pins and adduction of the cranial fragment The first caudal pin has broken The normal angle between the femoral head and shaft has been restored The tip of the trochanter has been pulled away from the acetabular roof Plaster cast for eight weeks

FIG 1942 — Check roentgenogram re figure 1941, five months later As there is not yet fusion across the epiphyseal line, the epiphysis of the head has slipped further and the neck and trochanter have been displaced cranially There is the same coxa vara as before the osteotomy The epiphyseal line has fused by now Bony union at the site of osteotomy

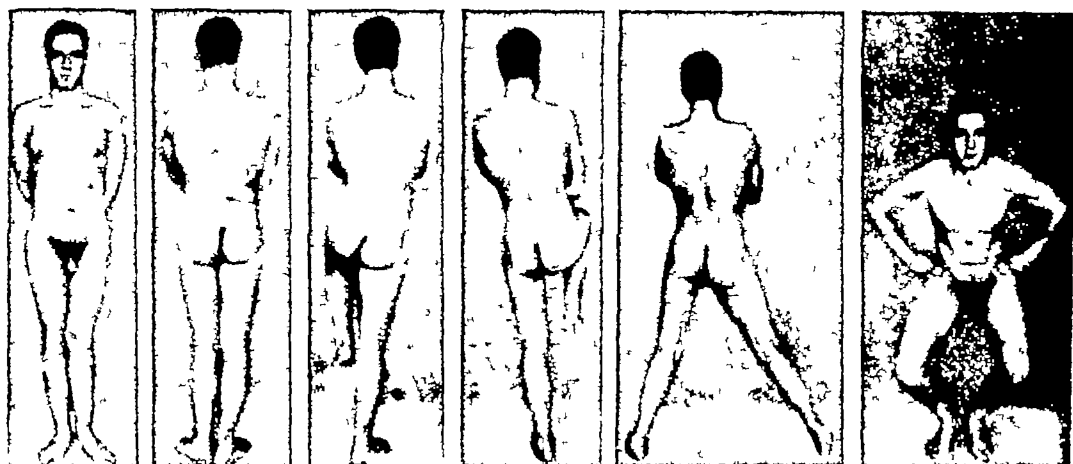


1943, March 14, 1931 1944, January 25, 1938

FIG 1943 — Check roentgenogram re figure 1942, one year later The femoral neck has slightly broadened Joint space is narrowed

FIG 1944 — Check roentgenogram re figure 1937, nine years later Coxa vara of 90° The femoral neck has developed well and become longer Normal width of joint space January 25, 1938

Immobilization is afforded by the big plaster cast as described on pages 1214—1228 Strong abduction and internal rotation are very important (figs 1914, 1915) so as to avoid redisplacement in the cast as in figure 1939



Figs 1945—1950—Photographs re figures 1937—1944 and comparison pictures re figures 1907 and 1908 Shortening of 3 5 cm Hip flexion 180°—130° External rotation free, internal rotation 1/3 of normal Left thigh weaker than right thigh Trendelenburg sign slightly positive on the right Abduction possible through 10° on the left side as against 40° on the right side. He walks with a slight limp He can walk for one hour without a rest Piercing pain in the thigh after overexertion Employed as a bus driver



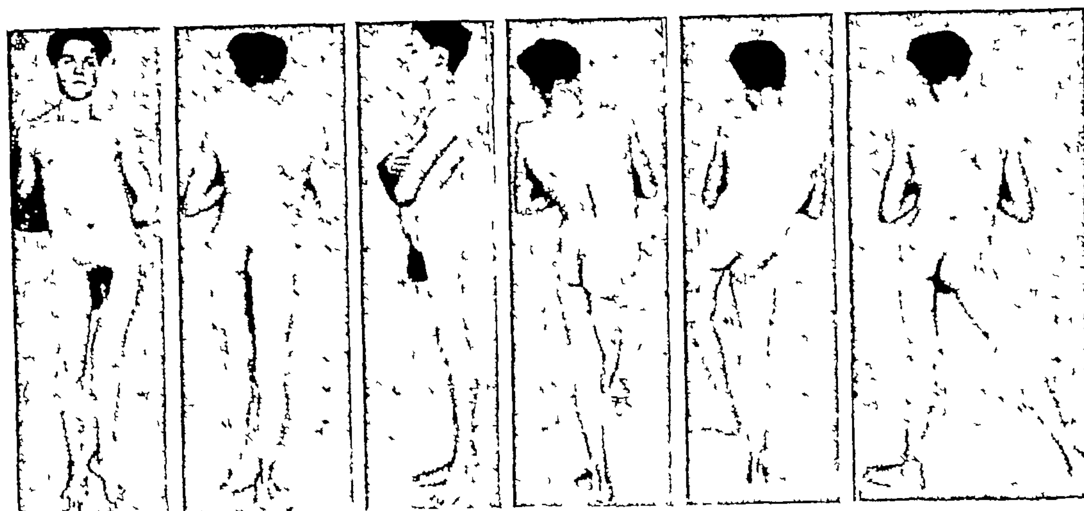
1951, October 21, 1937



1952, December 21, 1937

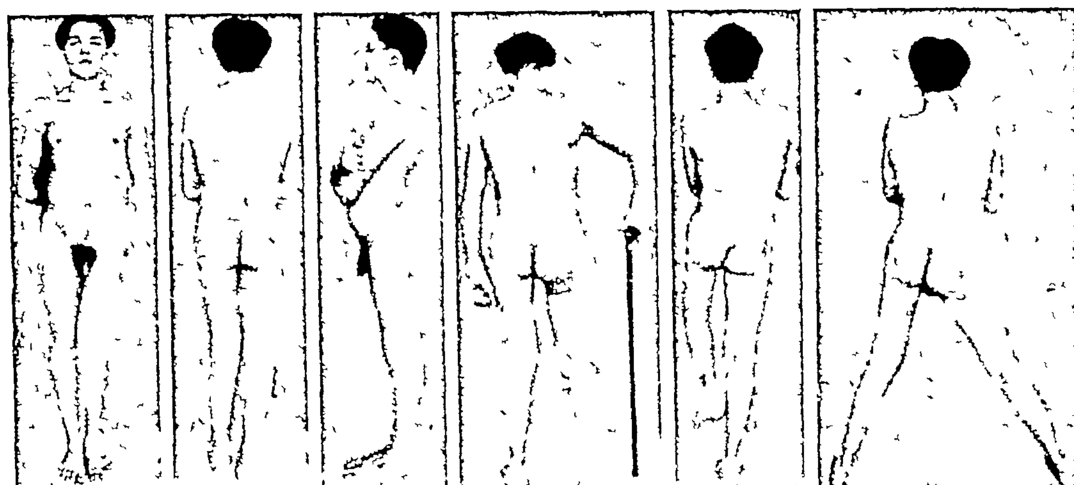
Fig 1951 - Coxa vara, adduction and external rotation following a separation of proximal femoral epiphysis in a 17 year old stableboy (figs 1953-1958) who slipped and fell on his left hip He could continue working but felt pain and limped After another fall five days later he could no longer walk Was treated elsewhere without reduction but with a plaster cast for six weeks The roentgenogram 1½ years later shows bony fusion of the neck with the displaced epiphysis The cranial part of the joint space is much narrowed, the joint surface of head and acetabulum are irregular Marginal exostosis from the acetabular roof

Fig 1952 Check roentgenogram re figure 1951, two months after the subtrochanteric osteotomy The distal fragment was abducted through 30° and rotated internally through 25°



October 21, 1937

Figs 1953—1958 —Photographs re figure 1951 Marked adduction, external rotation and flexion of the hip Apparent shortening of 5 cm, he cannot touch the floor with the heel Increased lumbar lordosis, scoliosis convex to the right side Markedly positive Trendelenburg sign on the right



December 27, 1937

Figs 1959—1964 —Photographs re figure 1952 and comparison pictures re figures 1953—1958, nine weeks after the subtrochanteric osteotomy Adduction, external rotation, flexion and shortening have disappeared The heel can touch the floor Lordosis and scoliosis have disappeared, Trendelenburg sign less marked

Check Roentgenograms After application of the plaster cast, new roentgenograms must be made in both planes

Exercises The patients are kept in bed in the plaster spica From the first day on, the toes must be extended and flexed as far as possible Also, both arms must be exercised

Period of Immobilization The plaster cast must remain for at least four months If the epiphysis has not fused after this time, a new plaster cast must be applied or further immobilization ensured by percutaneous wires or a

three-flanged nail. In any case, the immobilizing mechanism must not be removed until there is fusion across the epiphyseal line. Figure 1940—1943 prove that redisplacement of the epiphysis can occur with too short an immobilization, i. e., removal of the cast before fusion of the epiphysis and metaphysis.

Further Treatment. After removal of the plaster spica, an Unna's paste boot is applied to the foot and lower leg, and during the daytime an elastic bandage is worn round the knee (see page 1284). The knee joint is exercised on the knee flexion apparatus (figs. 1574, 1575) for five minutes twice a day to begin with, and the exercises are extended by five minutes per session daily if no complaints arise.

Massage and passive movements must be avoided, since they irritate the hip joint. If reduction has been complete and the epiphyseal line has closed, joint motion will become normal by itself within a short time. If, however, there is displacement, one will never improve mobility by forceful methods but only cause it to be still more limited.

Treatment of Slipped Proximal Femoral Epiphysis with Drugs and Hormones

Injections of pituitary extracts and even testicular transplantation have been recommended, and used elsewhere. We have not seen any successful results in patients so treated.

Further Observation of Patients with Slipped Proximal Femoral Epiphysis

The genitalia usually develop well later on (figs. 1907—1909) and libido develops normally. It would be interesting to investigate the generative faculty of these patients and the hereditary factors involved in this disease. This would of course make it necessary to follow a great number of these people over a long period. More will doubtless become known about this interesting disease in the future.

Avoidance of Late Complications Following Slipped Proximal Femoral Epiphysis

Most of the late complications after slipped proximal femoral epiphysis might be avoided if, after the onset of pain in the knee and a limping gait in juveniles between 10 and 16 years of age, not only the knee but also the hip were examined both clinically and roentgenologically. In the clinical examination one should look particularly for limitation of internal rotation and for pain on rotation of the limb. Anteroposterior roentgenograms of the whole pelvis should be made with the limbs in external and internal rotation and then with the patient in the lithotomy position. If the roentgenograms show the typical changes, three to five percutaneous wires should be drilled in or a three-flanged nail inserted to prevent any significant, or any further, slipping.

If, however, displacement of the epiphysis has already occurred with sudden pain, inability to walk and external rotation of the limb, reduction and immobilization with percutaneous wires or a three-flanged nail or in a

thoracopelvic plaster hip spica should be carried out within the first few days If this were done, one would never be compelled to treat long-standing cases with their unfavorable prognosis and protracted period of treatment

Treatment of Delayed Cases of Separation of the Proximal Femoral Epiphysis with Closed Pertrochanteric Osteotomy and Thoracopelvic Hip Spica

Formerly we treated adduction and external rotation contractures developing after slipped proximal femoral epiphysis with closed pertrochanteric osteotomy as described on page 1098 and with the big thoracopelvic plaster hip spica for eight weeks

When the epiphyseal line was fused to a large extent, as in figure 1928, the results were good (figs 1933—1936) Figure 1930 shows the roentgenogram made 27 years after such operation. There are no signs of arthrotic changes The man works as a farmer high in the mountains and feels no pain even after heavy work

When the epiphyseal line has not fused (fig 1940), redisplacement of the head will occur in spite of perfect reduction (fig 1941) if the plaster cast is removed after only eight weeks (fig. 1942) Immobilization must therefore be maintained until the epiphyseal line has closed

Osteotomy in the femoral neck region should be advised against, since this often disturbs the nourishment of the head

Treatment of Delayed Cases of Separation of the Proximal Femoral Epiphysis with Wedge Osteotomy Plus Nail and Plate

Inasmuch as the danger of infection has been minimized by the use of antibiotics, we now treat delayed cases of slipped proximal femoral epiphysis as a rule with open wedge osteotomy instead of with the closed transverse one The technique is described on page 1332. When a tracing is made of the roentgen image of the proximal end of femur and cut transversely distal to the lesser trochanter as in figure 1926, the size of the base of the wedge to be removed can be accurately determined by overlapping the two parts to the desired degree If a three-flanged nail is driven in and the osteotomy site is bridged with a plate secured with screws to the nail and to the femoral shaft (figs 1879, 1980 c, 2130), no plaster cast is required

Period of Recumbency If the wound heals uneventfully, the patient is allowed up three weeks after operation

Removal of Nail and Plate They can be left permanently if they cause no disturbance

Questions We Should Ask Ourselves to Avoid Failures in Treating Cases of Separation of the Proximal Femoral Epiphysis

1 Have I examined the hip joint as well as the knee joint in all patients between 10 and 16 years of age who have complained of pain in the knee or who have begun to walk with a limp? And have I looked particularly for limitation of internal rotation in the hip joint with the hip and knee

in right-angle flexion as well as for pain on rotation of the limb, expecially when the appearance of the patient suggested endocrine disorder?

2 Have I made roentgenograms of the whole pelvis in the anteroposterior projection and with the limbs first internally rotated, then externally rotated, and then with the patient in the lithotomy ("frog") position?

3 Have I, having found abnormal roentgenographic changes in the epiphyseal region to be present, examined the red cell sedimentation rate to exclude an infectious cause?

4 Have I, after having excluded infection as a cause, drilled in percutanously four or five stainless steel wires or inserted a three-flanged nail in order to prevent slipping of the epiphysis?

5 Have I, in case the epiphysis had been found already displaced, reduced the displacement within the first few days by gentle manipulation with *slight traction, abduction and internal rotation of both lower limbs*?

6 Have I then, after reduction of the displacement, fixed the epiphysis by inserting four or five stainless steel wires or by applying a thoracopelvic hip spica with the limb in abduction and marked internal rotation?

7 Have I then made new antero-posterior and lateral roentgenograms?

8 Have I forbidden weight-bearing for three months after reduction and immobilization?

9 Have I removed the wires, the three-flanged nail (if these are to be removed at all) or the thoracopelvic hip spica only after roentgenograms have shown the epiphyseal line to have closed?

58. FRACTURES IN THE TROCHANTERIC REGION (PERTROCHANTERIC FRACTURES)

Mechanism. Fractures in the trochanteric region are usually caused by violent external rotation of the limb, the body being twisted upon the firmly-held limb, or by a fall on the hip with simultaneous twisting of the body toward the sound side Fracture in the trochanteric region with twisting of the body to the affected side is very rare, it causes the so-called "type IV" fracture through the trochanters (figs 1968—1970)

Types of Pertrochanteric Fracture In the region of the trochanters there occur four different types of fractures The *first* are those through the base of the neck of the femur but outside the joint capsule Displacement is usually slight (fig 1965), but coxa vara may occur In the *second type* the fracture goes through the trochanters The leg is adducted and externally rotated A gap occurs cranioventrally between the two fracture surfaces, and there is coxa vara The periosteum is preserved about the dorsal part of the fracture (fig 1966) In the *third* and *commonest type* the base of the neck of the femur is deeply driven into the spongiosa of the trochanteric mass (figs 1967, 1971, 1973) and there is extreme coxa vara with marked external rotation of the limb The lesser trochanter is frequently broken off and displaced medially in varying degree (figs 1973, 1975—1978) In the *fourth type* the line of fracture traverses the region of the trochanters near the base of the femoral

neck Sometimes the lesser trochanter is broken off and displaced medially (fig 1968) The base of the femoral neck presents an unusually long point caudally This is not impacted into the trochanters, as in the type III, but rather the shaft of the femur is displaced cranially parallel to the medial fragment Sometimes the fracture line runs through the cranial portion of the lesser trochanter to the lateral side of the tip of the greater trochanter (fig 1969) In type IV fractures the limb is only slightly rotated externally Moreover, the neck of the femur is displaced dorsally and the angle between the fragments is open ventrally, whereas it is open dorsally in the first three types of fracture This type IV fracture probably results from internal torsion of the leg

Recognition The patients suffer from severe pain in the hip and can no longer walk In the commonest types of fracture — types II and III — the limb is externally rotated completely so that the foot comes to rest on its outer edge This is in contrast to the findings in cases of medial fracture of the femoral neck, in which the limb is externally rotated only 45° to 60° within the first few days In type IV, external rotation is as a rule only slight

Complications Following Pertrochanteric Fractures Without treatment these fractures heal in external rotation with coxa vara and shortening of 2—4 cm This causes severe disturbance of the gait with limping and persistent pain External rotation is a more serious handicap than coxa vara Coxa valga resulting from excessive traction is rare Shortening of 1—2 cm without external rotation is of no consequence However, lengthening of 1—2 cm may cause considerable trouble Limitation of motion of all joints of the limb and atrophy of the muscles may develop The most serious complication is non-union (fig 1980 g), always a consequence of excessive traction

Avoidance of Complications Following Pertrochanteric Fractures These complications can always be avoided by good reduction, sufficiently-long immobilization, and correct exercises Bony union will always occur in this fracture if it is treated properly, i e, if excessive traction is avoided

Treatment of Pertrochanteric Fractures

As in all other bone fractures, the dangers of distraction and infection arise from improper treatment

Every fracture is followed by devitalization and absorption of from 1 to 3 mm. of bone from each fracture stump. An opportunity must, therefore, be given the fracture stumps to approach each other. The aim of treatment should be to produce a shortening of from 1 to 10 mm. after every fracture, and under no circumstances to produce a lengthening. This statement may cause some surprise, because up till now the aim has always been to *eliminate* any shortening The amount of shortening for which one should strive is usually 1 cm or less The disastrous sequelae of lengthening of a fractured bone through distraction are described in Vol I/pp 25—27 and in M N[1]/pp 98—127, and are shown in figures 1980 e—g

[1] M N = *Medullary Nailing of Kuntscher* by Lorenz Bohler, translated by Hans Tretter, Baltimore, Williams & Wilkins, 1948





1971 1972

Fig 1971 —Coronal section through a specimen of pertrochanteric fracture with impaction of the neck into the base of the trochanter and with marked coxa vara (type III fracture)

Fig 1972 —Comparison picture re figure 1971, after reduction of the fracture The original neck-shaft angle has been restored A large cavity in the base of the trochanter remains after the neck has been pulled out (Courtesy Prof Schmorl)





1973 1974

Fig 1973 —Roentgenogram of an impacted pertrochanteric fracture with marked coxa vara The lesser trochanter is broken off and displaced medially

Fig 1974 —Check roentgenogram re figure 1973, after reduction The angle of the neck has been restored and the external rotation corrected The lesser trochanter has been restored to its correct position The cavity at the base of the trochanter is not shown in the roentgenogram There is slight overtraction, as the fracture gapes at the caudal end

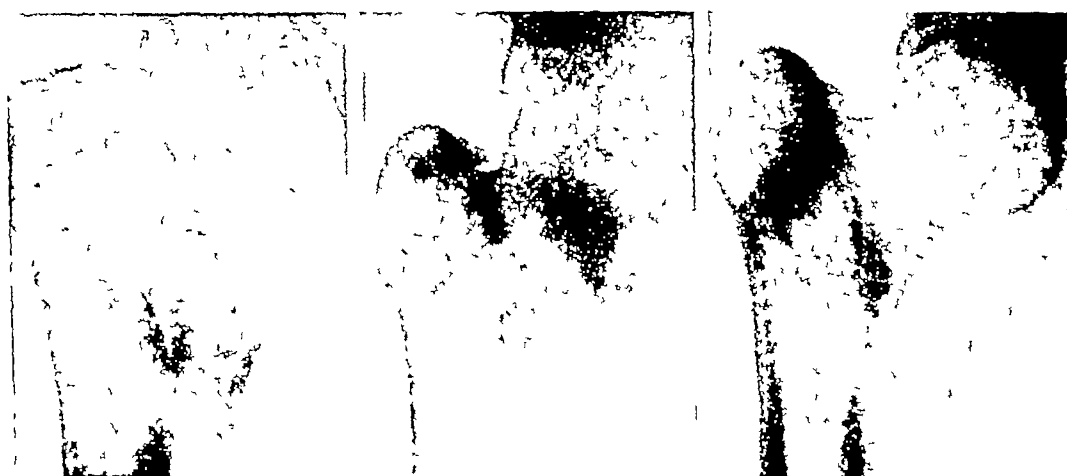


1975, December 31, 1937 1976, January 9, 1938 1977, January 20, 1938

FIG 1975—Pertrochanteric fracture in a 65 year old female, weighing 70 Kg, who fell on the street Severe skeletal decalcification Coxa vara and marked external rotation The fragments are not impacted Lesser trochanter displaced far medially Treated with tibial pin traction of 10 Kg

FIG 1976—Check roentgenogram re figure 1975, ten days later External rotation overcome The coxa vara position has changed into a coxa valga position because traction of 10 Kg was too strong for this elderly female with weak muscles Slight diastasis in the joint Traction therefore diminished by 3 Kg

FIG 1977—Check roentgenogram re figure 1976, eleven more days later, under traction of 7 Kg Perfect alignment of the two main fragments Coxa valga now absent The displacement of the lesser trochanter is of no concern



1978 1979 1980

FIG 1978—Pertrochanteric fracture with very long medial spike of bone at the lower end of the neck Marked external rotation, shortening, fracture of the lesser trochanter.

FIG 1979—Check roentgenogram re figure 1978 Traction in abduction has produced a coxa valga position Shortening eliminated

FIG 1980—Check roentgenogram re figures 1978 and 1979, three months later Bony union in satisfactory position Weight bearing started as early as in the seventh week has corrected the coxa valga deformity

Case 1 A traction weight of 10 Kg was used in the 65 year old, obese and weak female shown in figures 1975, whose body weight was 70 Kg The consequence was a valgus position and slight hip joint diastasis The valgus disappeared when the traction weight was diminished by 3 Kg The suggestion had been made in this case that the valgus be corrected by diminishing the abduction or by applying lateral traction to the thigh But a coxa valga cannot be corrected by these methods unless the traction weight is diminished at the same time Diminution of traction by itself eliminated the existing overcorrection valgus within a short time

Case 2 In the 28 year old strong man shown in figure 1980 e, whose body weight was 58 Kg, a traction weight of 10 Kg, i e one-sixth of the body weight, was applied, instead of the proper weight of 8 Kg This produced a gap of 7 mm between the fragments (fig 1980 f) As this excessive traction was kept up for four weeks, it produced non-union and coxa valga of 70° Marked decalcification of the bone is seen (fig 1980 g) After freshening of the fragments, medullary nailing and bone grafting, the fracture united and the man could walk again one year later But it took one more year for him to achieve full strength and mobility If medullary nailing had been carried out as early as one week after the accident, the patient could have started walking three weeks later and should have been fully capable of work four months later

First Check Roentgenograms On the second day, or at the latest on the third day, new anteroposterior and lateral roentgenograms should be made to see whether angulation and lateral displacement have disappeared and, above all, to allow recognition of eventual valgus position — a sign of excessive traction

Changing the Traction Weights If the anteroposterior roentgenogram shows a valgus position as in figure 1976 or a diastasis as in figure 1980 f, the traction weight must be decreased In case of pronounced coxa vara the traction weight should be increased In type III fractures with originally pronounced coxa vara it is sometimes expedient to retain a slight coxa vara of 120° in order to keep small the cavity remaining after reduction in the base of the trochanter (fig 1972) This cavity will then be filled more rapidly with callus

The second check roentgenograms should be made one week later

Further check roentgenograms are then made every other week

Femoral Pin or Wire Traction In the fourth week, supracondylar pin or wire traction must be applied to avoid overstretching the ligaments of the knee joint (see page 1186)

Further treatment is carried out as discussed on pages 1200—1204

Exercises and occupational therapy are described on pages 1204—1209

Period of Immobilization Fractures of type I require 12 to 14 weeks to unite Fractures of type II unite within 7 to 8 weeks, those of type III within 10 to 14 weeks depending on the amount of displacement, if distraction is avoided Fractures of type IV as a rule need 10 weeks

To avoid failures, one should ask oneself the questions listed on pages 1198, 1202 and 1207

Treatment of Pertrochanteric Fractures with the Thoracopelvic Hip Spica

We have never used the thoracopelvic hip spica for the treatment of closed and aseptic fractures, but we did use it for infected gunshot fractures. When this large plaster cast is used it must reach from the axillae to the tips of the toes as described on pages 1214—1228, but with the difference that the

limb must not be rotated internally but rather kept in mid-position between internal and external rotation. One should ask oneself the questions listed on page 1226.

Treatment of Pertrochanteric Fractures with Osteosynthesis Using Three-Flanged Nail and Plate

During the last years we have operated on most of our cases of pertrochanteric fracture provided the patient's general condition was good. We have done the operation under cover of antibiotics and have used rust-proof, amagnetic steel nails, washers, screws and plates. The advantage of this treatment, if carried out properly, is that the patients can get up in the fourth week and be discharged from the hospital in the fifth week. Otherwise, hospitalization is nearly three times as long. Furthermore, with this treatment the joints remain mobile.

Time of Operation. A pin or wire is put through the tibial tuberosity immediately after the patient's admission and appropriate weights are applied. Then we carry out the detailed clinical examinations (see page 1256) and wait until the marked swelling has subsided before operating. This usually takes eight to ten days. The 15 second breathing test should be carried out (see page 1256).

Use of Antibiotics. The night and the morning before the operation, penicillin is given and then is continued for three more days. If the patient develops a fever, penicillin is continued until the temperature is again normal.

Extra-articular nailing of the femoral neck is carried out under local anesthesia as described on pages 1257—1278. The fragments must be well reduced before they are nailed.

Application of the Plate. When the three-flanged nail has been placed well, an 8 cm. long plate is placed on the lateral aspect of the femur and fixed to the nail with the big screw and the washer (fig. 1678). Then four holes are drilled into the femoral shaft for the four screws which are to secure plate to shaft. The screws should be 35 to 45 mm. long; they should project 3 to 4 mm. through the medial cortex to ensure sufficiently firm fixation.

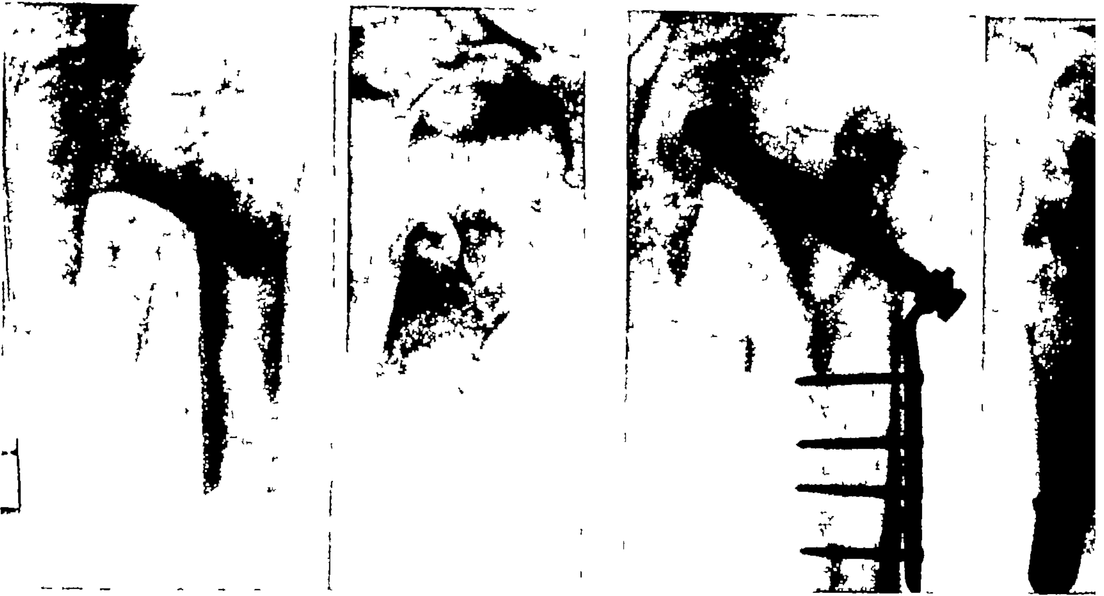
Wound Closure and Dressing. The vastus lateralis, fascia lata and skin are usually closed without insertion of a drain. The wound is covered with a compression bandage (spica trochanterica, not inguinalis, see "Verbandlehre" fig. 93).

Exercises are carried out as after femoral neck nailing (p. 1283).

Weight-Bearing. If the wound heals uneventfully, the patients are allowed up after three weeks. They can usually leave the hospital after four weeks. By contrast, when traction treatment is used, hospitalization averages 10 to 14 weeks.

Questions We Should Ask Ourselves to Avoid Failures When Operating on Pertrochanteric Fractures

These questions are the same as those concerning the operation for medial adduction or varus fractures of the femoral neck (see pages 1291—1295).



1980 a, b, February 11, 1954 1980 c, d, March 17, 1954

Fig 1980 a, b—Pertrochanteric fracture of the femur with coxa vara of 100⁰ and av of the lesser trochanter in a 69 year old female who fell on the street. After five days c traction a three-flanged nail and an 8 cm long plate were inserted

Fig 1980 c, d—Check roentgenograms re figures 1980 a and b, five weeks later Good pc of fragments, nail and plate in both views The displacement of the lesser trochanter doe impair normal function Patient could get up and start walking three weeks after oper



e, January 8, 1948 1980 f, January 10, 1948 1980 g, September 14, 1948 1980 h, Jan

Fig 1980 a, b—Pertrochanteric fracture of the femur with coxa vara of 100⁰ and avul weight 58 Kg) in a motorbike accident Coxa vara of 110⁰ The lateral view (M N/fig 3 shows a dorsal displacement by the full width of the shaft Wire traction of 10 insteac 8 Kg was applied *elsewhere*

Fig 1980 f—Check roentgenogram re figure 1980 e, two days later The coxa vara external rotation of the proximal fragment have disappeared The excessively strong trac has caused a gap of 7 mm between the fragments This remained for four weeks Only t was the weight reduced to 7 Kg, and then traction was removed entirely after eight we Coxa vara followed Ten weeks after the accident the fracture was reduced under gen anesthesia and a Whitman plaster (figs 1635—1640) was applied for eight more weeks. C vara recurred Seven months after the accident an attempt to nail the fragments failed

FIG 1980 g—Check roentgenogram re figure 1980 e and f, eight months after the accident On admission non-union, coxa valga of 70°, severe decalcification of the femur Operation with freshening of the bone ends, intramedullary nailing and fixation of a refrigerated beef bone onlay graft by three wire loops

FIG 1980 h—Check roentgenogram re figure 1980 e and f, after five years The femur has united in satisfactory position Full active motion of all joints No complaints



1981, September 14, 1935



1982, January 24, 1936

FIG 1981—Comminuted fracture of the greater trochanter in a 38 year old man who fell on his right hip from a height of 8 M He also sustained an *open* fracture of the skull and a perilunar dislocation of the right hand The limb was placed on a Braun splint

FIG 1982—Check roentgenogram re figure 1981, four months later The fragments have united Slight dragging pain only when walking long distances No complaints later on



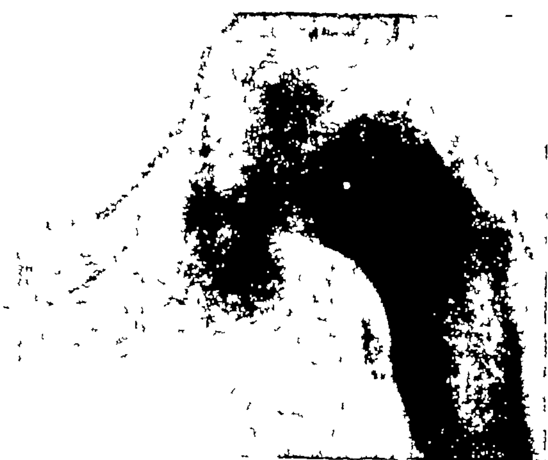


FIG 1983—Epiphyseal displacement of the left lesser trochanter sustained by a 13 year old boy as a result of a high jump Comparison with the sound side shows proximal displacement of the lesser trochanter by its full vertical diameter

Fractures of the Greater and Lesser Trochanters

Isolated *fractures of the greater trochanter* usually result from direct violence, e g, from a fall or blow on the hip We have never seen such a



1984, January 14, 1930 1985, January 17, 1930 1986, December 20, 1935

FIG 1984—High torsion fracture of the left femur in a 28 year old man who fell when skiing Varus, shortening, rotation and lateral displacement by full width of the shaft A large torsion wedge has been broken off medially

FIG 1985—Check roentgenogram re figures 1984, following three days' tibial pin traction Shortening, rotation and angulation have disappeared Lateral displacement unchanged

FIG 1986—Check roentgenogram re figures 1984 and 1985, six years later Site of fracture thickened Satisfactory neck-shaft angle, no shortening, no rotation Normal appearance Had traction for nine weeks and could walk without a cane one week later Three months later he could again take up sports Full range of active motion in all joints These fractures can also be treated with an intramedullary nail The torsion wedge is fixed with wire loops or screws



1987, December 15, 1937 1988 1989 April 15, 1938 1990

FIGS 1987, 1988—High torsion fracture of right femur in a 75 year old female who fell in her room Severe shortening, rotation, varus and anterior angulation Was treated with pin traction for three weeks and Unna's paste traction for seven more weeks Now we no longer use Unna's paste or adhesive plaster traction

FIGS 1989, 1990—Check roentgenogram re figures 1987 and 1988, four months later All displacements have completely disappeared Satisfactory callus formation Can walk without a cane Knee motion 180°—80° All other joints show a full range of active motion

fracture resulting from muscle-pull The bone is sometimes severely comminuted in these fractures (fig 1981) Displacement is as a rule not severe

Treatment The injured limb is placed on a Braun splint or a cushion Usually the patients can get up again after a few days and resume their work after a few weeks. Treatment with a thoracopelvic hip spica with strong abduction of the leg as for a fracture of the femoral neck has been suggested and carried out, but such treatment is superfluous, since delayed cranialward displacement of the trochanter never occurs Such treatment is, in fact, even harmful, as the resulting limitation of joint motion will prolong the period of recovery



1990 a, b, December 3, 1953 — 1990 c, d, March 29, 1954

FIG 1990 a, b—Per- and sub-trochanteric fracture of the femur with varus, shortening and severe lateral displacement in the lateral view Sustained by a 41 year old man (body weight 60 Kg) who fell from a scaffolding 3 M high Treated with pin traction of 9 Kg for 13 days As the severe lateral dislocation could not be corrected, he was operated on and internal fixation was afforded with a three-flanged nail, three wire loops and a plate 14 cm long

FIGS 1990 c, d—Check roentgenogram re figures 1990 a and b, four months later Patient got up six weeks after the accident The fragments united in satisfactory position Knee motion 170°—95° All other joints, including the hip, actively free When the greater trochanter is preserved, intramedullary nailing with additional wire loops secures greater firmness (M N / figs 540—553 and 657—670)

Fractures of the lesser trochanter very rarely occur as isolated fractures, but they are often combined with pertrochanteric fractures (figs 1973—1980)

In juveniles, *epiphyseolysis of the lesser trochanter* is seen (fig 1983) It is usually caused either by a jump from some height or by sudden, unexpected

torsion In the first few days after this injury, flexion of the hip is impossible, expecially in a sitting position

Treatment If the limb is placed on a Braun splint or a pillow and moist compresses are applied, discomfort disappears after a few days Joint motion and limb strength should be normal again after a few weeks The application of a big plaster cast with the hip in right-angle flexion, as done by some surgeons, is superfluous and harmful, since it impairs joint motion for a more or less extended period

59. FRACTURES IN THE PROXIMAL AND MIDDLE THIRDS OF THE FEMORAL SHAFT

Origin. Fractures in the proximal and middle thirds of the femoral shaft are usually caused by great violence, e g , forceful torsion as in a fall when skiing, in a fall from a great height, or by the impact of a heavy object such as might occur if one were buried by heavy material or run over by a heavy vehicle

Types of Fracture One sees torsion fractures in which there is a big wedge of bone broken off (figs 1984, 1990 a, b, 2091, 2099 and 2100, M N /figs 161, 162, 570, 571) and much less often torsion fractures without such a wedge (figs 1987 and 1990, M N /figs 540, 571), oblique "angulation" or "bending" fractures with or without an "angulation wedge" (a fragment broken off and lying at the concave or "open-angle" side of the fracture) (figs 2001, 2002, 2048—2053 and 2101), transverse "shearing" fractures (M N /figs 108, 109, 554—563), double fractures (figs 2038, 2039 and 2045, M N /figs 133, 574, 649, 650), and severely comminuted fractures (figs 2107 and 2108, M N /figs 618, 619)

Displacements In fractures of the proximal third of the femoral shaft there is always varus angulation with the angle open medially (figs 1984, 1987 and 2155, M N /figs 749, 767) and anterior angulation with the angle open dorsally (figs 1988 and 2156, M N /figs 750, 768) Both fragments are rotated externally

In fractures of the middle third of the femoral shaft there are, as a rule, varus angulation and posterior angulation with angles open medially and ventrally And there is usually some degree of shortening

The *clinical examination* is carried out as described in Vol I/pp 10 through 12 The lengths of both lower limbs must also be measured and compared

The **recognition** of fractures of the femoral shaft is easy, since all positive and all suggestive symptoms and signs of fracture (see Vol I/p 5) are usually present Normally the limb shows marked angulation, abnormal mobility and swelling. The patient has pain and cannot walk. Roentgenograms made after administration of local anesthesia reveal the exact location and type of fracture

Possible Complications Following Fractures of the Femoral Shaft. With no treatment at all or with improper treatment, shortening, angulation and/or

rotation deformity, limitation of joint motion, arthrotic changes and/or circulatory disturbances with atrophy of the muscles and decalcification of the bones often develop in these cases At present, non-union results most frequently from excessive continuous traction Non-union may also result from infection, from immobilization which is inadequate or is maintained for too short a period or from early passive motion and massage (M N /figs 748—753) There is in addition the danger of infection with the use of pins and wires and with operative treatment

Avoidance of Possible Complications Following Fractures of the Femoral Shaft Most complications can be avoided if these fractures are treated properly either by continuous traction with appropriate weights or by intramedullary nailing Non-union in the absence of infection most frequently results from the use of excessive continuous traction Infection in the pin or wire holes can usually be avoided by careful daily checking of these sites

Treatment of Fractures of the Proximal or Middle Third of the Femoral Shaft with Continuous Pin or Wire Traction

Every fracture is followed by devitalization and absorption of from 0.5 to 3 mm. of bone from each of the fracture stumps An opportunity must, therefore, be given the fracture stumps to approach each other. The aim of treatment should be to produce a shortening of from 1 to 10 mm. after every fracture, and under no circumstances to produce or allow a lengthening. This statement, as previously mentioned, may cause some surprise, because up till now the aim has always been to *eliminate* any shortening The amount of shortening for which to strive is usually 1 cm or less

The disastrous consequences of distraction or "lengthening" in a fractured femur as a result of excessive traction are described in Vol I/pp 25—27 and M N /pp 98—127 and are shown in figures 2111, 2112 and 2145—2158 in this volume and in M N /figs 735—747, 754 and 783

Formerly we treated all recent closed fractures of the femoral shaft with continuous traction Now we use the intramedullary nail (Kuntscher) in many cases In long rotation fractures reaching up into the trochanteric region we sometimes use a three-flanged nail with a long plate (figs 1900 a—d)

The equipment necessary for continuous traction is listed on page 1182
How to prepare and check the equipment,
how to prepare the bed,
how to dress the Braun splint,
the advantages and disadvantages of skeletal traction,
the dangers of skeletal traction (distraction and infection), and
the avoidance of these dangers are described on pages 1183—1188

Local anesthesia of the fracture site and the pin or wire holes about the tibial tubercle,
roentgenograms,
positioning of the patient in the warmed bed,
placing of the fractured limb on the Braun splint,
insertion of the pin or
drilling of the wire through the tibial tubercle;

setting up of the overhead gallows, adjustment of the scissor-shaped spreader and placement of the wooden foot-rest,

application of the forefoot traction, and

selection of the appropriate traction weights are all described on pages 1188—1200

Reduction of the Fracture Shortening should be corrected until shortening of 1 cm or less remains (vide supra et infra) Lateral displacement should be corrected until the fragments at least touch each other Angulation and rotation, however, must be corrected *completely* Reduction is usually left to the continuous traction with appropriate weight and with the limb properly supported on a Braun splint Lateral traction or lateral pressure pads are seldom required

Treatment of Shortening Shortening must never be overcome completely lest the fragments gape because of absorption of the ends of the fracture stumps (vide supra) *Lengthening* a fractured bone by excessive continuous traction or by other means is singularly dangerous The disastrous sequelae are described in Vol I/pp 25—27 and in M N/pp 98—127 Correct determination of the traction weight is discussed on pages 1179—1181 Care must be taken to use only one-tenth and not as much as one-seventh of the body weight in the case of a feeble patient **At present, the most severe complications in these fractures are caused by excessive traction.**

Recognition of Distraction Caused By Excessive Traction In transverse fractures this can easily be detected from the gap seen between the fragments on the roentgenogram (fig 1980 f, M N/figs 761, 762)

In torsion fractures with a long torsion wedge, lengthening is often difficult to recognize because there may be lengthening between one main fragment and the broken-off torsion wedge while there is shortening between the torsion wedge and the other main fragment A valgus position of the fragments in a fracture of the proximal half of the femoral shaft treated in continuous traction is a rather definite sign of lengthening (fig 1976) Prolonged absence of callus is another sign At the end of the third week, cloudy callus is usually visible in the roentgenograms if a shortening of at least 4—5 mm has existed from the beginning (M N/figs 283, 284, 288 and 291) If no callus is visible at the end of the fourth or fifth week, after two months (M N/figs 301, 302), or after six months (M N/figs 289, 290), the conclusion can be safely drawn that excessive traction was exerted for some period

Treatment of Lateral Displacement In torsion fractures (figs 1987—1990) or oblique fractures (figs 2001—2004), lateral displacement can usually be corrected easily by appropriate longitudinal traction If a lateral displacement by the full width of the shaft remains, as in figures 1984—1986, no ill effects will result provided excessive shortening, rotation and angulation are corrected In transverse fractures the correction of lateral displacement is only possible if the fragments are first distracted This may be allowed for only a short time, i e, for a few minutes during manipulation or up to 1—2 days in continuous traction, if one is to avoid all the complications described above Complete correction of lateral displacement is required only in juxta-articular

fractures, especially in transverse fractures In cases such as that shown in M N /fig 555, this will succeed only if at first a lengthening is achieved by means of strong traction and if the distal fragment is then pulled ventrally with a sling as in figure 2009 The sling must pull on the central end of the distal fragment, and the cord with a weight of about 5 Kg must run over a pulley cranially When the dorsal displacement of the distal fragment has thus been overcome within 24—48 hours, the traction weight must be diminished again to the normal amount so that the fracture stumps can approach each other and muscle tension can press them together

On the other hand, it must be stressed again that lateral displacements by the full width of the shaft are of no functional or cosmetic concern in fractures of the femoral or humeral shafts provided there is no rotation, no angulation and no excessive shortening (not more than 2 0 cm) This is demonstrated in Vol I/figs 261—268, 271—293 and 2016—2026

We need not, therefore, absolutely insist on correction of lateral displacement in the shaft region Under no circumstances should long-lasting, excessively strong traction be exerted in the attempt to achieve such correction

Consequences of Angulation Uncorrected angulation causes static disturbance and leads to arthrotic changes, especially in the knee joint Sometimes such arthrotic changes develop as late as after 10—20 years [1]

Treatment of Angulation in the Frontal Plane As long as there is shortening, a *varus* angulation can properly be corrected by increase of the traction weight and by stronger abduction The overhead beam and the Braun splint should, however, never be placed lateral to the edge of the bed

If the varus angulation amounts to less than 10°, it can be overcome by excentric traction (figs. 1992, 1993), i e, by pulling in the direction of abduction With valgus angulation, conversely, the traction should pull more in the direction of adduction (figs 1994, 1995)

If a varus angulation cannot be corrected by increase of traction and by excentric pull, a pad is placed against the lateral side of the peripheral end of the proximal fragment and another pad against the medial side of the central end of the distal fragment (fig 1991) If this does not suffice, lateral traction toward the injured side must be applied to the pelvis

Valgus is corrected by appropriately reversed application of these measures

Treatment of Angulation in the Sagittal Plane Anterior angulation that existed before reduction always disappears in fractures of the proximal third if the proper weight is used for longitudinal traction Sometimes, however, posterior angulation follows

Anterior angulation in fractures of the middle third usually disappears when the pulley for longitudinal traction is elevated (fig 1996) It is only seldom necessary to press dorsally the peripheral end of the proximal fragment with a pad (fig 1996)

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[1] Bohler, L Der schadliche Einfluß von Achsenknickungen auf die Gelenke des Beines Der Chirurg, *4* 1942

Posterior angulation in fractures of the middle and distal thirds usually disappears when the pulley for longitudinal traction is lowered so far that the traction cord passes at the level of the tips of the toes or the metatarsal heads (fig 1611) and when the knee-angle of the Braun splint is at the same time moved proximally (fig 1998, 2008) If this does not suffice, a stitched pad can be placed underneath the fracture site (fig 2009) The most effective way of correcting posterior angulation is by means of a sling which pulls the distal fragment ventrally In figure 2009 this procedure has changed posterior into anterior angulation Care must be taken to pull only the distal fragment ventrally and not the proximal one along with it If the sling lies too far proximally, the proximal fragment also will be displaced ventrally and the displacement of the

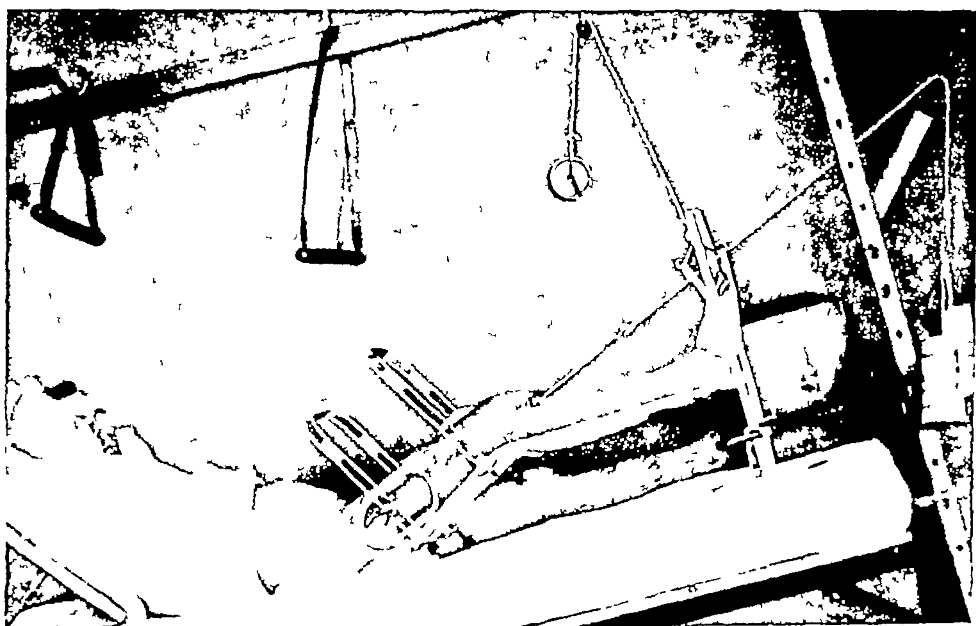


FIG 1991 —Old fracture at the junction of the middle and distal thirds of the femur, united in varus After osteotomy the shortening was overcome by longitudinal traction of 10 Kg To correct the varus, a pad was applied laterally just proximal to the fracture site and another pad medially just distal to the fracture If varus cannot be corrected by this method, lateral traction with a sling round the pelvis is exerted towards the injured side and weighted with 4—5 Kg At present after an osteotomy we usually insert a medullary nail as in M N /fig 693—696 and 705—734, instead of using pin traction

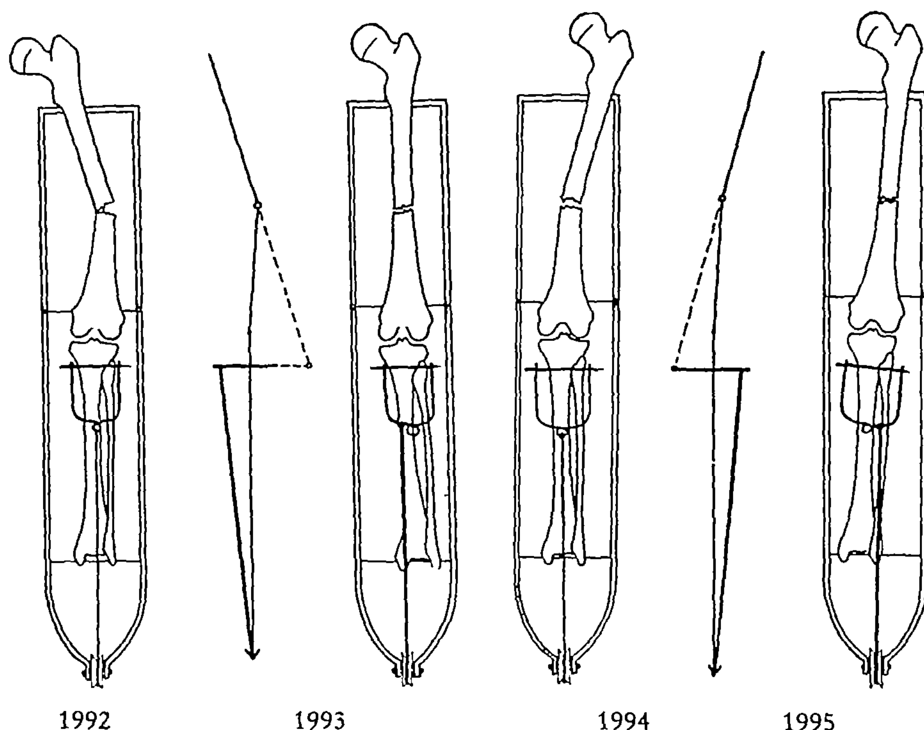
fragments will be increased To avoid this, the site of the fracture should be sketched on the skin On each rounds one should then check to see that the sling still lies distal to the sketch of the fracture on the skin Ventrally directed wire traction through the proximal end of the distal fragment has often been recommended, but in view of the danger of infection we have rarely used this method As a means of correcting posterior angulation in the proximal third, a sling is placed dorsally at the level of the fracture site as in figure 2009 — where, however, it is shown being used for a fracture in the distal third in which it has caused over-correction This pull should be used only if the distal fragment lies slightly dorsal to the proximal one

Treatment of Rotation Rotation can easily be corrected with a splint placed on a completely even bed (boards under firm mattresses) if the medial margin of the foot is positioned vertically (fig 1610) If this cannot be achieved by forefoot traction, the lateral end of the pin is properly suspended from the gallows by a strong calico bandage (figs 1604 a—d)

First check roentgenograms are made on the second or third day at the latest to see whether the angulation has been corrected and especially to make sure that the traction is not excessive

The second check roentgenograms are made after one week

Further check roentgenograms are then made every second week Care should be taken that the site of the fracture be projected in the center of the



1992 1993 1994 1995

Figs 1992, 1993 —A varus angulation can be corrected in a properly-weighted longitudinal traction by stronger abduction or by eccentric pull, i e, by fixing the traction cord medially on the stirrup and thus tending to tilt the tibia and the distal femoral fragment into valgus One should take care with such excentric fixation that the wire or pin does not lie too obliquely, as it might then slide in the bone and cause infection If the varus is not corrected by this means, a pad is placed against the lateral side of the distal fragment and traction is applied to the pelvis towards the injured side

Figs 1994, 1995 —Valgus can sometimes be overcome by exerting longitudinal traction primarily on the lateral side of the stirrup by excentric attachment of the traction cord, thus tending to tilt tibia and distal femoral fragment into varus

film and that a neighboring joint is also shown The marking of the fracture site is described on page 1201

Increasing and Decreasing the Traction Weight If the slightest gap occurs between the fragments, the traction weight must be decreased accordingly If there is shortening of more than 10 mm, the weight must be increased

Warning Against Too Frequent Change of Position and Alignment In order not to disturb callus formation, position and/or alignment of the fragments should not be changed too often

Infection of the Pin or Wire Holes A piece of gauze incised from one edge to the center and soaked in alcohol is placed on the pin or wire site if one detects inflammation there on the daily rounds or if the patient complains of local pain there The inflammation often subsides after this If not, a new pin or wire should be inserted at another place and the old one removed The old pin or wire holes are then dressed by sterile gauze with a drop of balsam of Peru These pin or wire holes should never be wiped or even washed out They usually heal within a few days

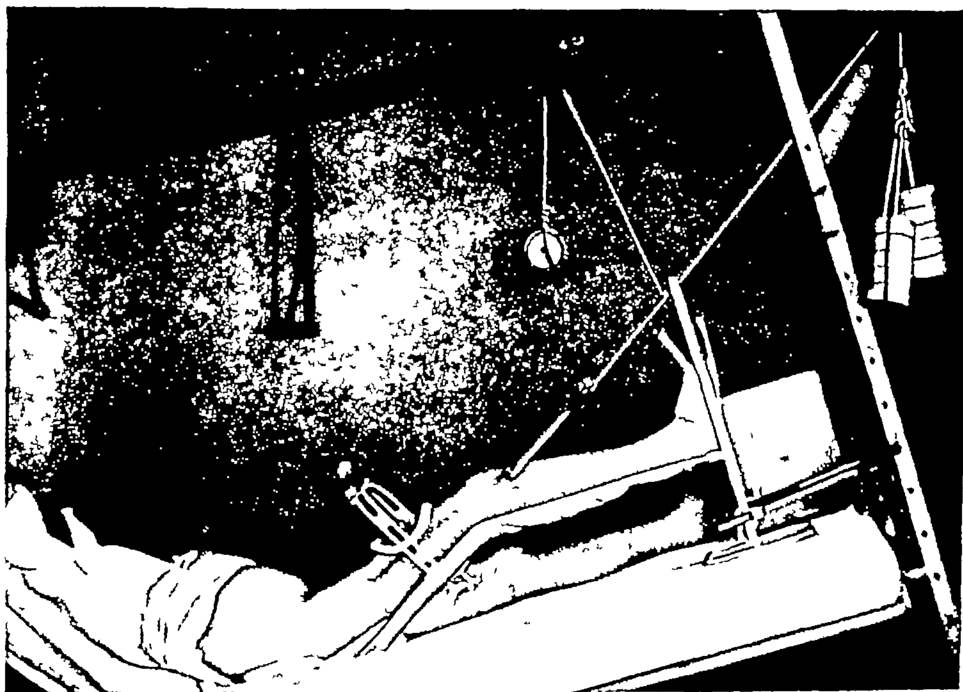


FIG 1996—Anterior angulation with an angle open dorsally can usually be abolished by elevating the traction cord If this fails, a pad is placed ventrally on the peripheral end of the proximal fragment

If a pin or wire begins to slide to one side it should not be driven back, but a new pin or wire should be inserted at a slightly different level and the old one removed

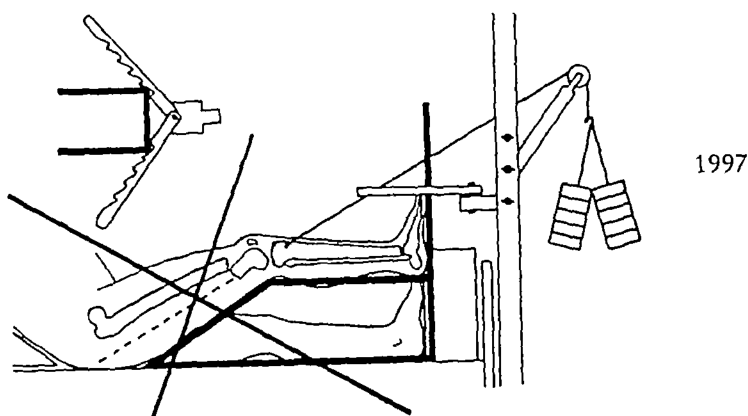
Exercises and occupational therapy are carried out as described on pages 1204—1208, viz

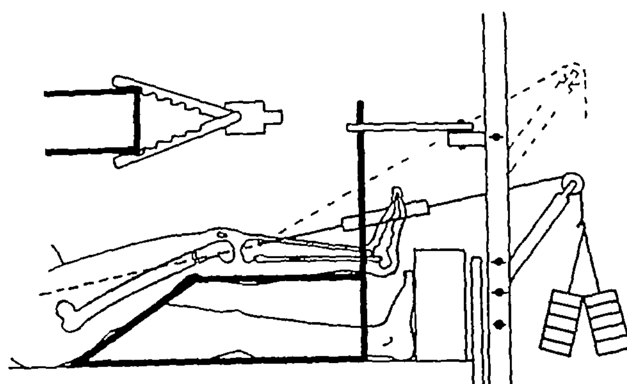
Daily active movements of the toes and the ankle joint through their full range,

Active contraction of the thigh muscles from the second week on,

Exercises of the sound limb on the knee flexion apparatus (figs 1574, 1575),

Exercises of the sound limb on the "mountain climber" (Vol I/figs 21, 22), and





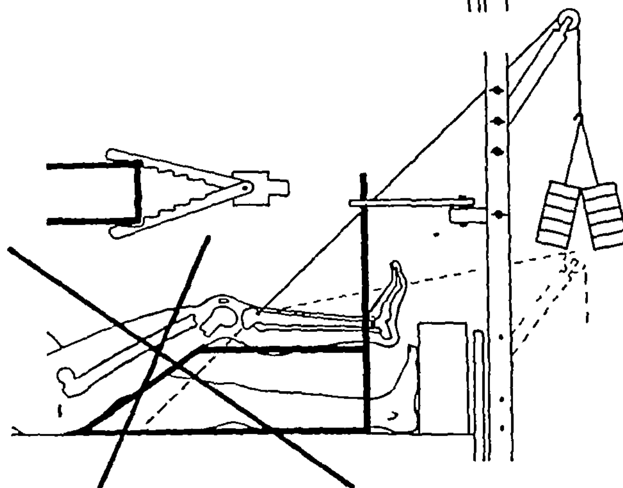


Fig 1997 —Angulation in the sagittal plane with the angle open ventrally (posterior angulation) in a supracondylar fracture of the femur cannot be corrected with the usual positioning of the patient and with the usual traction weight of one-seventh of the body weight

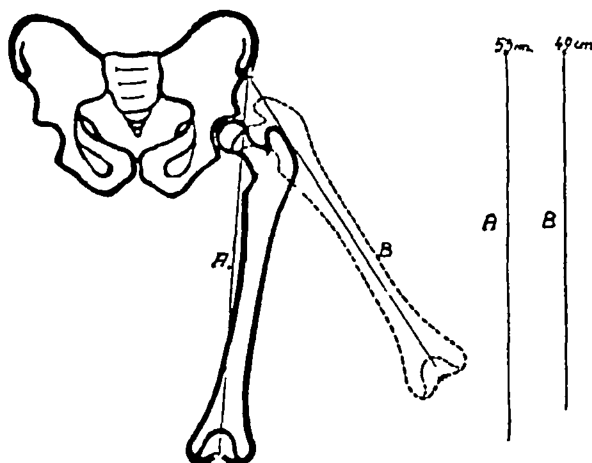
Fig 1998 a —Posterior angulation disappears with the use of proper traction weight when the angle of the splint is moved proximally, i e, away from the knee joint toward the fracture site, and the pulley with the longitudinal traction is lowered so far that the traction cord passes at the level of the metatarsal heads (fig 1611)

Fig 1998 b —If with posterior angulation the pulley with the traction cord is lifted too high, angulation becomes worse in spite of one's moving the angle of the splint proximally and in spite of the use of no excessive traction weight One can "see light" between the splint and the popliteal fossa

Lying flat for a time each day (fig 1604 d)

Transposition of the Pin or Wire to the Femur in the Fourth Week Tibial traction exerted for more than four weeks causes loosening of the knee ligaments and subsequent impairment of joint motion Therefore a pin or wire should be inserted through the femur under local or general anesthesia in the fourth week and the one in tibial tubercle removed As pull proximal to the knee joint is more effective than pull distal to it, the traction weight should then be diminished by 1 Kg Each change of the traction weight, as well as the initial weight used, should be noted on the patient's chart

Position of the Pin in the Femur When a pin is used it should be inserted exactly at the junction of the metaphyseal and diaphyseal regions, a place which can always be located very well When driven in too far distally it may enter the knee joint, when driven through the femoral shaft it may burst the compact cortical bone In that latter case the pin loosens soon, moves, and may cause infection



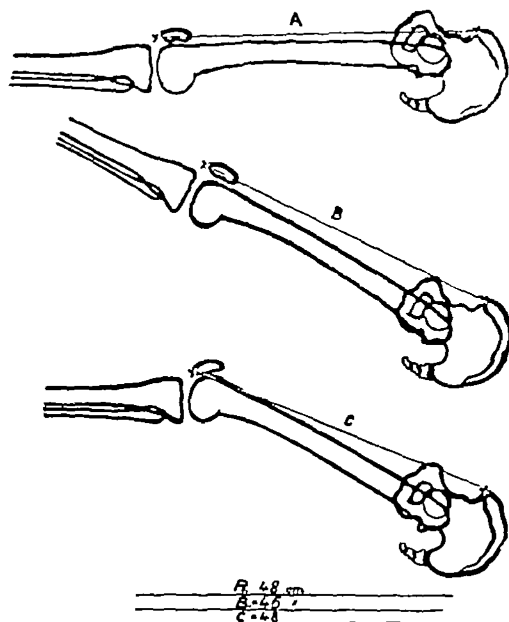
1999, sketched in September 1917

With abduction the greater trochanter approaches the pelvis Therefore, with 40° abduction the distance between the anterior superior iliac spine and the patella is 4 cm shorter than with adduction

If a wire is used, it too may be drilled through the femoral shaft

Measuring the Length of the Femur During Continuous Traction Measuring the length of a limb on a Braun splint is rather difficult The result can be depended upon only if all joints of the sound limb have been brought into the same flexion, abduction and rotation as on the injured side This is best accomplished by placing the sound limb also on a Braun splint To take the measurement, thumb and index finger holding one end of the tape measure are pressed to the caudal side of the anterior superior iliac spine while the thumb and finger holding the tape in the other hand are placed on the distal end of the patella To avoid deceiving oneself, one should not look at the tape while measuring the femur but should take the reading only after removing the tape and should then repeat the measurement Figures 1999 and 2000 show how different the same actual length may appear with different positions of abduction and flexion

Period of Immobilization Most fractures of the femoral shaft require 8—10 weeks to unite If distraction of only a few millimeters existed for but a few days, or if angulations were too frequently corrected, it would require 12—16 weeks or longer The traction weights should not be removed until the roentgenograms show satisfactory callus formation if one would avoid re-angulation Weight-bearing should be allowed only when the patient can actively lift his leg and when it is no longer sensitive to pressure or flexion If the site of the fracture becomes painful and swollen on weight-bearing, this is a sign that the callus is still too soft and is not yet capable of carrying such weight The limb must then be put in traction again to avoid angulation Sometimes a sling about the ankle joint with a traction weight of 3—4 Kg for two weeks will do



2000, sketched in September 1917

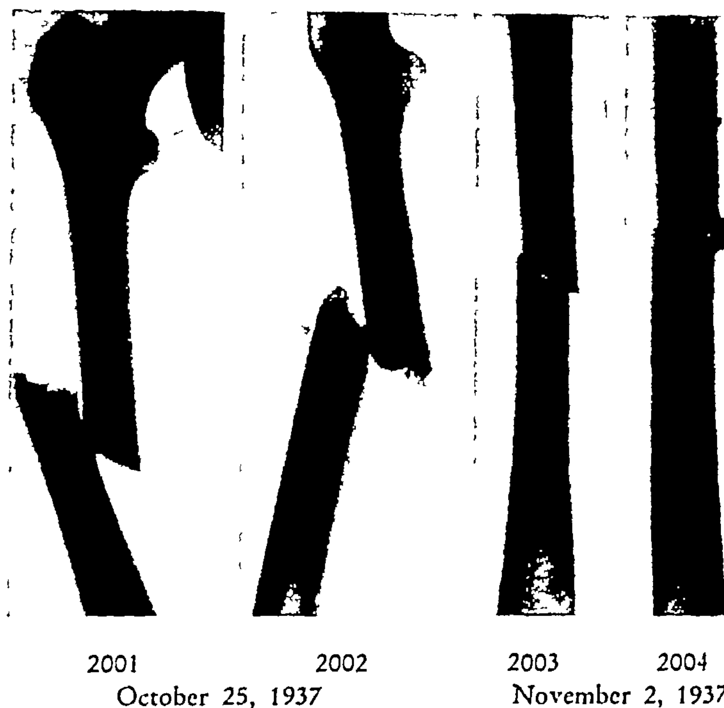
With flexion of the hip and extension of the knee the distance between the anterior superior iliac spine and the patella is 3 cm shorter than with extension of hip and extension of the knee or with equal flexion of hip and knee

Measuring the Length of Both Lower Limbs After the fracture has united and traction has been discontinued, the length of both limbs should be measured and compared in order that one may find out to what extent one has succeeded in avoiding a shortening of more than 1 cm A shortening of 0 5—1 cm is required for the reasons given on page 1383 and elsewhere It is interesting to note that very few case histories contain any reference to the length of the limb at the time when the traction was removed or the patient discharged from the hospital or outpatient department Most surgeons seem to have forgotten by the end of the treatment that all the trouble and dangers of traction, for which they had been responsible and which the patient had been called upon to bear, had had the sole aim of avoiding severe shortening, angulation and rotation of the broken limb As a rule, it is not before the

patient's incapacity is assessed that the length of the limb is measured The patient himself will soon notice the shortening if it is considerable

Measuring the Circumference of the Limbs For comparison, the circumference of both limbs should be measured round the calves and a hand's breadth above the upper margin of the patella In severe displacements and after thrombosis, the circumference of the broken thigh is often greater than that of the sound one

Measuring Joint Motion The range of motion of all joints of both lower limbs from the toes up to the hips should for comparison be measured with a goniometer and the measurements entered on the temperature-pulse-respiration sheet of the chart as well as in the progress notes



2001 2002 2003 2004
October 25, 1937 November 2, 1937

Fig 2001, 2002 —Flexion (leverage) fracture of the femur in midshaft sustained by a 28 year old woman who was hit from behind by an automobile Shortening, lateral displacement, rotation and angulation of the fragments

Fig 2003, 2004 —Check roentgenograms re figures 2001 and 2002, one week later Ideal reduction The fragments are well apposed and there is no fracture gap Treated by tibial pin traction weight equal to one-seventh of the body weight The fragments have been reduced with proper positioning of the patient and with appropriate traction without any attempted manipulation Such results are rare Usually a lateral displacement remains, but this is of no concern At present we usually treat transverse and short oblique fractures of the femur with Kuntscher's medullary nail if the patient's general condition is good

Further Treatment The lower leg and the knee joint become swollen after every fracture of the femur when weight-bearing is begun This can best be avoided by putting on an *Unna's paste boot* from the interdigital folds of the toes up to the knee and by putting an elastic bandage round the knee for the days The technique of applying the Unna's paste boot is described in "Verbandlehre," where the required equipment is also mentioned (see

also page 1284) In young patients the Unna paste boot can be removed in just 2 to 4 weeks Old patients may need it 3 to 4 months, especially if they had suffered from varicose veins beforehand Sometimes it is desirable to apply an Unna paste boot on the sound leg as well

In addition, *baking* is used but for not longer than 10—15 minutes at a time The knee must not be overheated, since this causes circulatory disturbances with discoloration of the skin, decalcification of bones and pain in the knee

Short wave diathermy is as a rule appreciated by the patients The *exercises of the injured limb on the knee flexion apparatus* are carried out as described on page 1207, and

walking with the quadripod canes is begun as described on page 1207

Why we *avoid massage and passive motion* is also discussed on page 1207

Operative Treatment of Extension Contracture of the Knee Joint If excessive weights were used for continuous traction and if, as a result, consolidation of the fracture took several months, extension contracture of the knee joint always develops It can be overcome by operation (see page 1473)

Resumption of Work In juvenile patients, normal strength and motion sometimes return as early as three to four weeks after consolidation of the fracture, while in old patients this usually requires some months and depends on the patient's age, on the amount of primary displacement and on the time necessary for consolidation If the fracture united in good position, and if consolidation did not take longer than ten weeks, normal strength and motion usually return after a few months It is not necessary to fill this time with "polypragmasy," e g, with the use of various invisible irradiations, lamps of different colors, X-ray therapy, injections or exercises on highly complicated apparatus Apart from his doing the regular active exercises and participating in light sports, it is advisable that the patient begin with some light work as a preparation for the serious work of his or her normal occupation Administrative difficulties raised by labor offices of insurance companies, etc, can usually be overcome

Questions We Should Ask Ourselves to Avoid Failures When Treating Fractures of the Femoral Shaft by Pin or Wire Traction

They are the same as those listed on pages 1198, 1202 and 1207

TREATMENT OF FRACTURES OF THE FEMORAL SHAFT BY PLASTER CAST

For most of the closed fractures of the femoral shaft, continuous traction is the most suitable treatment Transverse or short oblique fractures are better treated with the medullary nail provided the patient's general condition is good, the necessary equipment is at hand, and above all that a surgeon experienced in the technique of such operation is present

In some cases, however, the plaster cast is to be preferred It must, for example, be used when delirium tremens is imminent or has already developed This is the only method which will protect such patients from severe damage, and it can also be recommended for most other mental patients if medullary

nailing is for some reason not possible Formerly we also used it when there was delayed callus formation or difficulty in correcting angulation in traction Now we use the medullary nail in these cases Nailing or a plaster cast is also necessary if the patient must be transported over a long distance *If for some reason a patient with a fractured femur cannot be admitted to the hospital, he should be put in a plaster cast* Rarely will it be possible to achieve a satisfactory result with continuous traction in a private home, where a suitable bed and a good nursing staff are usually absent. If an unpadded plaster cast is applied within the first few days after the injury *it must* under any and all circumstances be split *right through from end to end and down to and including the last thread* to avoid severe circulatory disturbances

Case 1 A strong young man first lost a leg and then his life after a closed femoral fracture On the day of injury, an adhesive plaster traction bandage was applied on a remote farm As the circular coils of the bandage were pulled too tight and swelling increased, the lower leg became gangrenous He was taken to a hospital where the leg was amputated through the infected tissue of the lower leg and not through the fracture site of the femur The consequences were infection of the fracture hematoma and death resulting from general septicemia

Case 2 A 12 year old boy *sustained a torsion fracture of the femur while skiing* On the same day a plaster cast was applied, allegedly according to my method(!) Although the boy shouted with pain a few hours later, the plaster cast was not split until the third day Foot and lower leg were black and dry and had to be amputated At the trial, the expert witness declared that the unpadded plaster cast, alleged to have been applied according to my directions, was responsible for the unfortunate result of the treatment He further maintained that the application of an unpadded plaster cast was a mistake My rules say that *every plaster cast applied in a severe fresh injury must immediately be split right down to the skin* throughout its full length in order to avoid circulatory disturbances I should like to point out here that, of all my rules, this one demanding immediate and complete splitting of the plaster cast is the most important one

In our hospital, 20 to 30 new plaster casts are applied daily. We have treated about 100,000 fractures with the unpadded plaster cast Only once, in 1927, has gangrene developed, that being a gangrene of the lower leg following a fracture of the ankle and developing because the surgeon — unfortunately inexperienced — did not in the first place split the plaster cast and then, when pain developed, gave analgesic injections instead of opening the cast This is the only unfortunate occurrence of this sort I can recall, since the strict order that every plaster cast applied after a fresh injury be split completely and at once, i e before the patient leaves the plaster room, has otherwise been adhered to most accurately in our hospital We also split the cast in old injuries when pain sets in and do not wait for the toes to become cyanotic and to lose their motion and sensibility

Position of the Leg in the Plaster Cast In fractures of the proximal half of the femoral shaft the plaster cast must be applied with the limb in strong abduction and reach up to the axillae (figs 1635—1640). The limb should not, however, be internally rotated A cast applied without the limb in abduction would lead to varus angulation of the fragments In fractures of the distal half of the shaft a plaster hip spica which reaches up to the costal margin suffices (fig 2081, 2082) In fractures of the distal third, a small pelvic ring affords sufficient security and allows the patient to sit more comfortably.

Application of the Thoracopelvic Hip Spica With slight variations it is applied like the thoracopelvic hip spica for femoral neck fractures (see pages 1214—1228) The patient is placed on the fracture table with knees and hips extended, with little or no abduction in fracture of the distal shaft (fig 1577) and with strong abduction in fracture of the proximal shaft (fig 1626) In the case of a patient to be kept recumbent in plaster it may be expedient to flex slightly the hip and knee (fig 2166 c)

Reduction The shortening should be corrected until it amounts to only 0 5—1 cm before application of the plaster cast Lateral displacement without any lateral diastasis of the fragments can be disregarded Angulation and rotation must, however, be corrected The limb is suspended at the knee so that it does not sag (fig 2165 c) The suspending sling must not be placed beneath the fracture, because the soft tissue would be squeezed in from either side and pushed ventrally The fragments would thus be deviated ventrally into anterior angulation When one has the impression from the external contours of the limb that position is good, a roentgen check can be made with the fluoroscope

First Roentgenograms If fluoroscopy shows good alignment, roentgenograms in the two main planes are made Persisting slight angulations are corrected by slight pressure and counter-pressure while the plaster cast in setting Fluoroscopy is repeated during application of the thigh part of the plaster in order that such slight angulations can be recognized and corrected in good time while the plaster is still soft This is better than correction later by wedging the cast

Second Roentgenograms After application of the cast, new roentgenograms should be made in both main planes

Checking the Circulation If the plaster cast is applied within the first couple of days after the injury, it must be split throughout its whole length right down to the skin to avoid possible interference with circulation With casts applied from the third day on, splitting is usually no longer necessary If, however, pain develops, the splitting must be done at once and not be postponed until the toes become blue, insensitive and motionless

Application of a New Plaster Cast If the cast was split, a new plaster cast is applied in the same manner 10—14 days later, i e, when the swelling of the leg has subsided This cast need not be split Fluoroscopy and roentgenograms are repeated as with application of the first cast

Exercises If circulation is normal and there is no pain, a walking caliper is then applied on the next day With this the patient can start walking In addition, arm exercises are carried out daily

Check roentgenograms are made one week later

Traction Treatment in the Plaster Cast These check roentgenograms made after a week sometimes show reangulation, since the femur is surrounded by thick muscles and does not lie so close to the plaster as to be firmly supported by it In such case the patient is put to bed and the foot part of the plaster cast is fastened to the outer edge of the foot-end of the bed This end of the bed is raised 30 cm so that the trunk then lies lower than the feet The

body tends to slide cranially out of the cast by the gravitational force of its own weight and thus puts traction on the fixed limb

Roentgenograms taken 2—3 days later usually show that the angulation has disappeared

Further roentgenograms must be made every second week

Period of Immobilization. The cast is maintained for 6 to 10 weeks depending on the amount of primary displacement, the age of the fracture and the firmness of the fracture at the time of application of the cast In recent fractures the cast must be left for at least eight weeks If it is removed too soon, reangulation will occur.

The further treatment is carried out as in fractures of the femur treated in continuous traction (see page 1200)

Questions We Should Ask Ourselves to Avoid Failures When Treating Fractures of the Femoral Shaft In Plaster

In addition to the questions listed on page 1226, the following questions should be asked

1. Have I applied a thoracopelvic hip spica with the limb strongly abducted in a fracture of the proximal half of the femoral shaft?
2. Have I placed the foot in mid-position between external and internal rotation and *not* in extreme internal rotation as in a fracture of the femoral neck?
3. Have I applied a pelvic hip spica without the thoracic part and without abduction in a fracture of the distal half of the shaft?
4. Have I suspended the limb at the knee and not at the fracture site?
5. Have I fluoroscoped the fragments in both views after adjusting the limb so that its external appearance suggested adequate reduction?
6. Have I made roentgenograms in both main planes before application of the plaster cast?
7. Have I fluoroscoped again when applying the thigh part of the plaster cast?
8. Have I corrected any angulation by appropriate pressure and counterpressure?
9. Have I made new roentgenograms after application of the plaster cast?
10. *Have I, in recent fractures of the femur, before the patient has left the plaster room, split at once the plaster cast throughout its full length and right down to the skin, to avoid possible circulatory disturbance?*
11. Have I applied a walking plaster 10 to 14 days after application of the split plaster cast?
12. Have I repeated fluoroscopy and roentgenogram at the time of application of the new plaster cast as was done at the time of application of the first cast?
13. Have I made new roentgenograms one week later?
14. Have I, in the case of reangulation, put the patient to bed, fixed the foot part of the plaster to the margin of the foot-end of the bed and then raised the foot of the bed so that the broken limb was again subjected to traction with the patient's own body as the traction weight?

60. FRACTURES OF THE DISTAL THIRD OF THE FEMORAL SHAFT

This group includes fractures of the diaphysis reaching as far proximally as 15 cm proximal to the knee joint Among these the fractures lying near the metaphysis, i e, the supracondylar fractures, are the most difficult ones to treat

Origin. At present, fractures of the lower third of the femoral shaft are most frequently seen after traffic accidents They also occur in falls on the foot or the knee, by the impact of heavy objects etc

Types of *Fractures* Transverse fractures (figs 2010, 2011) and oblique fractures (M N/figs 641, 642) are more frequent than torsion fractures (figs 2007, 2008, 2016, 2017, 2099 and 2100, M N/figs 671, 672 and 698) Comminuted fractures are not rare (figs 2005, 2016, 2023—2025, M N/figs 590, 591)

Displacements Contrary to what is seen in fractures of the proximal third of the femoral shaft, fractures of the distal third in normal bone usually show recurvation with an angle open ventrally (figs 2005, 2007, 2011, 2017, 2023—2025 and 2039) because the distal fragment is pulled dorsally by the gastrocnemius In healthy bone, antecurvature with an angle open dorsally (fig 2026, M N/fig 591) is rare, but it is common in bone which is atrophic and decalcified because of poliomyelitis, tuberculosis, marasmus etc The anteroposterior roentgenogram shows varus or valgus angulation depending on how the limb was placed for the examination For reduction it is essential to know from the roentgenogram whether the fracture surfaces face each other (fig 2024) or not (figs 2005, 2016—2021)

The *clinical examination* is carried out as described in Vol I/pp 10—12 Differences in shape or color, pulse, active motion and sensibility should be noted, since vessels and nerves are sometimes compressed or torn The bilateral difference in limb length should also be noted and recorded

The **recognition** of these fractures is easy, as it is also in fractures of the middle or proximal thirds (see page 1382) If the leg is pale, pulseless and insensitive, the distal fragment very likely presses on nerves or vessels or has torn them This may lead to huge swelling

Complications Following Fractures of the Distal Third of the Femoral Shaft. The worst early complication is rupture of vessels and/or nerves or the compression of the popliteal artery by the distal fragment angulated dorsally toward the popliteal fossa If the vessels and nerves are torn, gangrene of the leg will follow If they are only compressed, circulation will return provided the pressure is relieved by reduction before thrombosis of the vessel has developed Then the pale leg becomes pink Unsevered nerves can recover, too Improper treatment leads to posterior angulation which is extreme when excessive traction has been used and when the direction of the pull has been incorrect Pressure from the distal fragment may cause late disturbances of vessels and nerves and even pressure ulcers (figs 2149, 2150) *Excessive traction also causes irritation of the knee joint and thickening of the capsule with severe impairment of motion* Besides, the complications mentioned on page 1382 may



2005, December 2, 1953 2005 a, March 13, 1954

FIG 2005 —Supracondylar comminuted fracture of the right femur Typical angulation (recurvation) with the angle open ventrally Concomitant fracture of the head of the right tibia without displacement, open fracture of the shaft of the left femur and total dorsal dislocation of the foot Sustained by a 24 year old fireman who fell from a height of 30 meters

FIG 2005 a —Check roentgenograms re figure 2005, three months later As the right femur could not be reduced in traction, open reduction was done Through a lateral incision the ventral torsion wedge was fixed with two wire loops Then a blade-plate was angulated to 90°, the blade was inserted into the femoral condyles and the plate was fixed to the shaft with seven screws Varus of 10°



2006 October 14, 1951 2006 a, October 20, 1951 2006 b, June 18, 1952

FIG 2006 Supracondylar fracture of the left femur united in varus and antecurvature Sustained by a 28 year old flight captain in an airplane crash

FIG 2006 a Check roentgenograms re figure 2006, after wedge osteotomy and insertion of a long medullary nail across the knee joint The fragments are secured against rotation with a wire loop

FIG 2006 b —Check roentgenograms re figure 2006, eight months later and two weeks after removal of the medullary nail The lateral view shows a 10° recurvation

develop The most frequent sequela is recurvation with subsequent arthrotic changes resulting from altered relationships in the knee joint (M N /figs 639, 640)

Avoidance of Complications Following Fractures of the Distal Third of the Femur Rupture of nerves or vessels is caused by the trauma of the accident and cannot be avoided We have not yet been able to try suturing these ruptured vessels and nerves, because in our cases there has been such extensive



FIG 2007 – Roentgenogram re figure 1997 Supracondylar fracture of the femur with typical posterior angulation



FIG 2008 —Roentgenogram re figure 1998 a The joint "space" of the knee lies distal to the angle of the splint The angle of the splint has been pushed proximally so that it now lies dorsal to the fracture site as in figure 1998 a Thus posterior angulation has been combatted and overcome

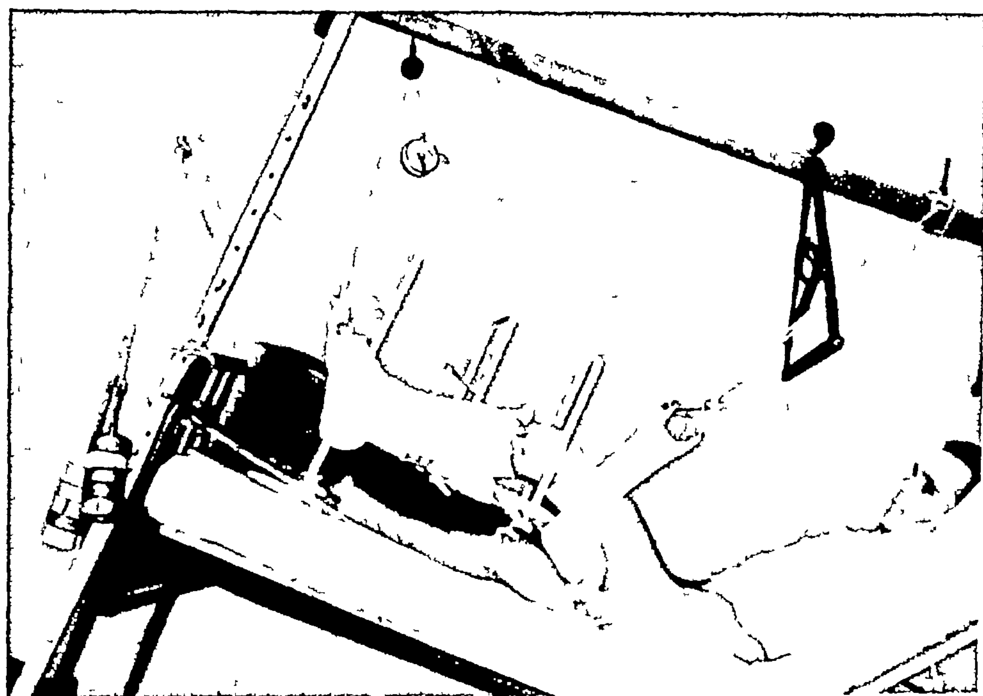
tearing and bruising of skin and muscles that there has been no alternative to primary amputation If vessels and nerves are only compressed by the distal fragment and not torn, this pressure can be relieved at once by appropriate positioning of the limb (fig 2008) Such positioning also avoids ultimate recurvation angulation

Treatment of Fractures of the Distal Third of the Femoral Shaft with Pin or Wire Traction

This is carried out as in fractures of the proximal or middle third (see pages 1383, 1388 and 1390) Treatment, especially of the supracondylar frac-

tures, is regarded as very difficult by most surgeons because of the great difficulty usually met in correcting the posterior angulation With positioning as shown in figure 1998 a, we have succeeded in correcting the posterior angulation in every one of over 100 personal cases This is shown in figure 2008 in the case of a long distal fragment and in figure 2016 in the case of a short one

The Bone-Joint-Muscle Unit in Supracondylar Fractures of the Femur The dorsally-angulated distal fragment cannot alone be brought into alignment with the proximal one because it forms one unit with gastrocnemius, lower leg and foot — a specific entity combining bone, joint and muscle Reduction succeeds only if the whole of this system is considered in bringing the distal

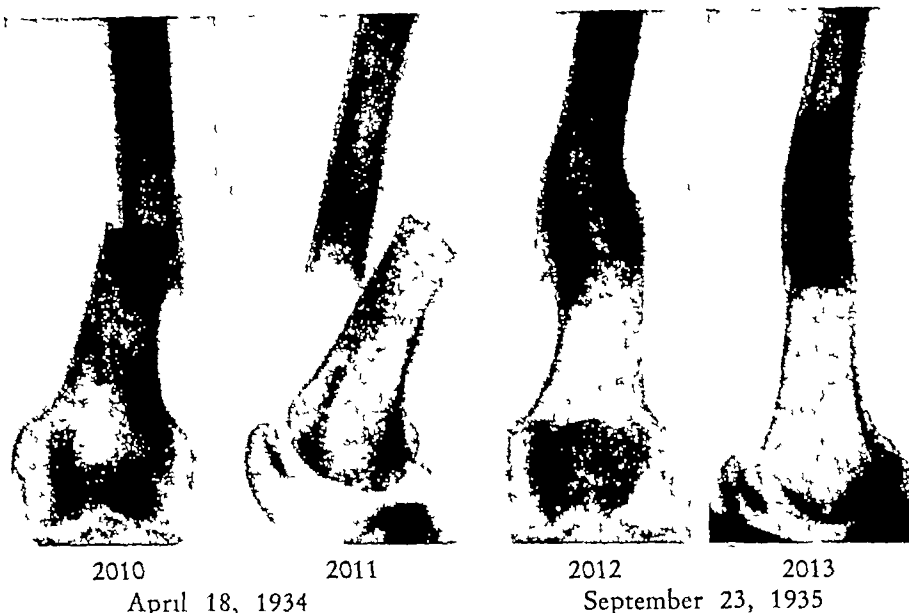


May 4, 1934

FIG 2009 — Supracondylar transverse fracture of the femur with typical displacement (compare roentgenogram in figure 2011) To correct the angulation and lateral displacement, oblique traction is exerted at the fracture site with a well-padded stockinet sling or a wire (Vol I/fig 364 r), if moving the knee angle of the splint proximally from the knee joint does not bring about the desired result By this traction arrangement the fragments were reduced The longitudinal traction pulls dorsal to the axis of the proximal fragment Lower leg plaster cast is for concomitant bimalleolar fracture with lateral dislocation of the foot Forefoot traction prevents external rotation If the patient's general condition is good we treat these fractures with Kuntscher's medullary nail (fig 2100, M N/figs 416 423 and 641 645) or with a strong, angulated blade-plate (fig 2005 a)

fragment and the proximal fragment into line (Vol I figs 242, 243) Since the distal fragment initially deviates only 30°—40° (fig 2011), the limb should not be positioned with the knee in pronounced flexion (of, e g, 90°). The knee-angle of the Braun splint, which is 150°, is the best

Moving the Braun Splint Proximally The recurvation with the angle open ventrally caused by the pull of the gastrocnemius and the short head of the



FIGS 2010, 2011 —Supracondylar transverse fracture of the femur in a 33 year old carpenter who was hit by a post Shortening, lateral displacement and typical angulation with the angle open ventrally (recurvation)

FIGS 2012, 2013 —Check roentgenograms re figures 2010 and 2011, 18 months later Bony union with 10⁰ antecurvature The lateral displacement is of no account Treated with tibial tubercle pin traction and vertical traction on the distal fragment (see figure 2009) From the fourth week to the tenth week, longitudinal traction exerted through a supracondylar pin in the femur Five months after the accident the knee motion was 170⁰—80⁰, free active motion of all the other joints With a patient in good general condition it is better to treat such a fracture with a medullary nail (fig 2100, M N /figs 408—423 and 641—648) or an angulated blade-plate (fig 2006)

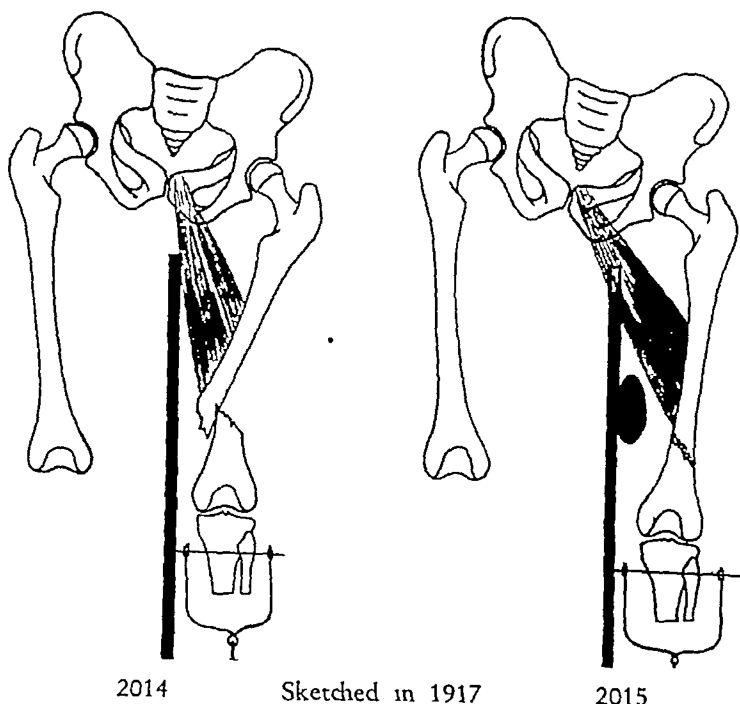


FIG 2014 —Supracondylar fracture of the femur with valgus due to oblique position of the pelvis and the pull of the adductor muscles

FIG 2015 —Correction of the valgus by a cushion or a pad along the medial side of the proximal fragment If the valgus cannot be corrected by this means alone, lateral sling traktion towards the sound side is applied to the pelvis

biceps femoris can easily be corrected by changing the position of the Braun splint and the scissor-shaped spreader When the Braun splint is moved towards the buttocks, the knee joint comes to lie distal to the knee-angle of the splint Thus the distal fragment, after over-riding has been corrected, is levered ventrally by appropriate traction and very easily reduced (figs 1998 a, 2007, 2008) If necessary, a pad may be placed dorsally at the fracture site If the Braun splint is pushed *too* far towards the buttocks, antecurvature results with an angle open dorsally (fig 2013) Alignment of the fragments is achieved only if (1) appropriate traction is used, i e, one-seventh of the body weight in strong patients and one-tenth in feeble patients or in open fractures, and if (2) the traction cord makes an "antecurvation" angle with the long axis of the femur (figs 1991, 1998 a, 2009 and 2011)



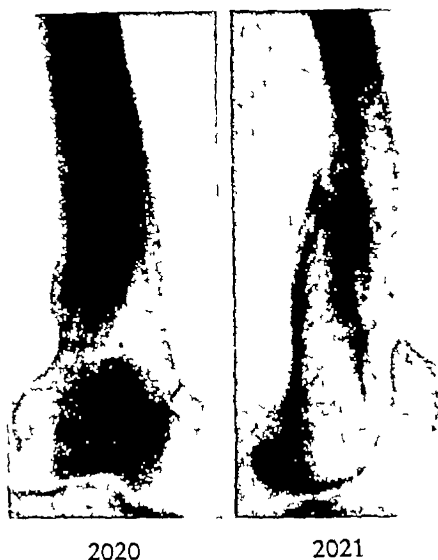
2016 2017, August 24, 1918 2018, 2019 October 17, 1918

Figs 2016, 2017 – Supracondylar leverage-torsion fracture sustained by a 32 year old soldier when a cavern was blown up on the Italian front Typical dorsomedial displacement of the distal fragment with the angle open ventrally Patella raised considerably by effusion of blood into knee joint (92 cc were withdrawn) If, in such a case, the distal fragment is pushed further medially on the very first day, it can then be moved *round the proximal fragment* ventrally Then both oblique fracture surfaces face each other and adequate reduction can easily be accomplished by longitudinal traction

Figs 2018, 2019 Check roentgenograms re figures 2016 and 2017, eight weeks later Fracture united Dorsal displacement of the distal fragment by the full width of the shaft Shortening and recurvation abolished, 7° valgus in the frontal view

Sometimes the dorsal *displacement* of the distal fragment cannot be corrected This displacement without angulation will do no harm even if it amounts to a full shaft's width provided the fracture site is more than 10 cm distant from the distal femoral articular surface, as figures 2018—2022 show in a patient after 36 years of observation

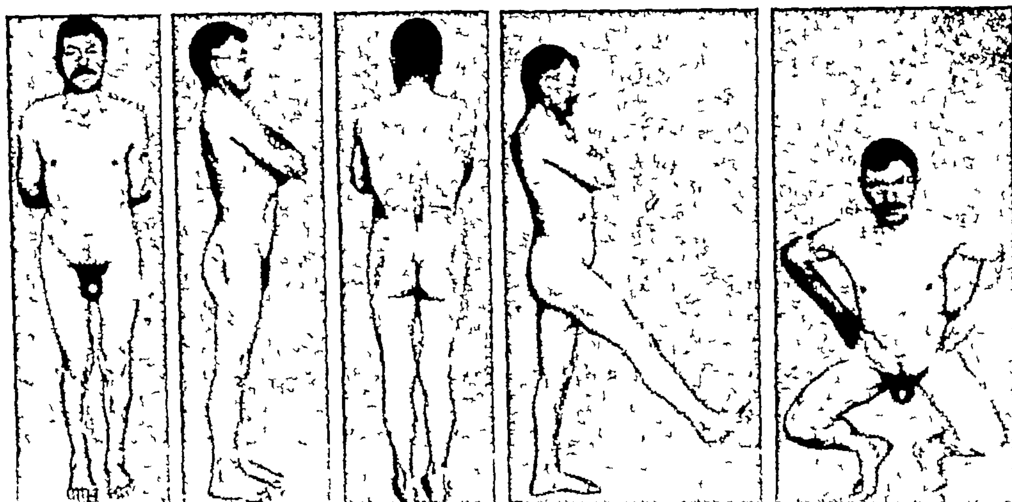
Manual Reduction of Sagittal Plane Displacement Reduction of such displacement may cause trouble in traction treatment, as shown in figures 2016—2021, if the fracture surfaces do not face each other Especially on the first



2020 2021

April 22, 1954

FIGS 2020, 2021 —Check roentgenograms re figures 2016—2019, 36 years later 7^{0} valgus and 10^{0} antecurvature The distal fragment is displaced dorsally by the full width of the shaft No arthrotic changes



January 16, 1938

FIG 2022 —Photographs re figures 2016—2021 This man, 52 years old when these photographs were taken, sustained a supracondylar fracture of his right femur (figs 2016, 2017) on August 24, 1918, when a trench was blown up on the Italian front On the following day he was admitted to the Military Hospital for Fractures and Gunshot Wounds of the Joints founded by me at Bozen and was treated in the same way as he would be nowadays On November 30, 1918 he was taken prisoner of war and marched long distances On August 16, 1919 he returned home Since then he has worked as a woodcutter in the Alps He has no complaints at all With the exception of a slight valgus, the limb shows essentially normal shape, especially in the lateral view Knee joint motion 170^{0}—60^{0}, full range of active motion in all other joints

day, reduction is often possible by guiding the distal fragment round the proximal one with the knee flexed and longitudinal traction applied If such reduction attempt has been successful, the limb is placed on a Braun splint with the fracture site on the angle of the splint as shown in figure 1998 a and with the traction weighted properly. If the roentgenograms show good position, pads are fixed along both sides of the fracture site so that the fragments cannot easily become redisplaced while the patient is being moved from the operating room to the station

Reduction of Lateral (Frontal Plane or Sagittal Plane) Displacement with Continuous Traction In short transverse fractures near the metaphysis, such displacement must be corrected by manipulation or by continuous traction, because if it remains it is harmful If manipulation fails to reduce the fragments, reduction may be accomplished in continuous traction A weight is used which is 3 to 4 Kg greater than normal, and within a few hours this causes gaping of the fragments Such distraction must be confirmed by fluoroscopy and/or roentgenograms As soon as this distraction has been achieved, reduction can usually be carried out easily by exerting pressure and counterpressure on the appropriate sides of the two fragments

Application of a Ventral Traction Sling By supporting the distal fragment in a sling (fig 2009) whose cord should not be fixed but should be weighted and run over a pulley, redisplacement in the sagittal plane can be avoided The sling also tends to prevent lateral displacement in the frontal plane because it compresses soft tissue about the fragments medially and laterally One must see to it, however, that the sling actually pulls on the distal fragment and not on the proximal one To best accomplish this, the level of the fracture site should be marked clearly with a red pencil on the skin On every rounds, then, one should make sure that the sling still lies distal to that marking on the skin

Treatment of rotation, first and second check roentgenograms; increasing or decreasing the traction weights, avoidance of too-frequent changes of position, treatment of pin-hole inflammation, exercises and occupational therapy, transfer of the pin or wire to the femur in the fourth week, care of position of the supracondylar pin or wire, and measuring the length of the femur during continuous traction — all these are as discussed in connection with fractures of the proximal or middle third of the femoral shaft (see page 1387—1391)

Period of Immobilization If reduction was achieved during the first few days and if the proper traction weights were used and no further manipulations were performed, these fractures are usually solid and capable of supporting weight-bearing within 6 to 8 weeks

After removal of the traction, treatment is carried out as in fractures of the proximal or middle third of the femoral shaft (pp 1392, 1393), viz., *measuring the length of both limbs, measuring the circumference of thigh and calf, examining joint motion, application of an Unna's paste boot, "baking" for not too long a period, giving diathermy, exercising the injured limb on the knee flexion apparatus and starting the patient walking with quadripod canes*

Massage and passive motion should be avoided

Late Damage to Vessels and Nerves and Pressure Ulcers in Fractures of the Distal Third of the Femoral Shaft Such damage has been reported by some authors We have never seen it in our personal cases It occurs only if the limb is positioned with extended knee so that the distal fragment presses on the vessels Late perforation of the popliteal artery has been described in a case of closed fracture of the femur treated on a Thomas splint with the knee extended (Watson-Jones)

This damage develops mainly with the use of excessive traction weights, e g 19 Kg as in the case shown in figures 2145—2150 Even 28 Kg traction has been reported This excessive traction causes severe pain in the knee joint with consequent cramps of the calf muscles resulting in increased flexion of the distal fragment, especially if the pulley for the longitudinal traction is fixed too high as in figure 1998 b By such excessive traction in such improper direction, the knee is lifted from the splint ventrally so that one can see light between the splint and the skin of the popliteal fossa (fig 1998 b) The distal fragment may thus be caused to press against the nerves until paralysis sets in, and even against the skin so that large pressure ulcers may develop there (figs 2149, 2150)

Joint Damage by Excessive Continuous Traction Excessive continuous traction irritates not only the sensory nerves but also the vascular nerves This causes passive hyperemia with fibrous induration of the tissue The knee becomes thickened, the ligaments shortened and the capsular recesses obliterated If, however, traction acting distal to the knee joint is weighted properly, thickening about the knee will not develop If tibial traction with correct weight is left in place for longer than four weeks, the joint will become loose but not thickened Many surgeons blame severe bleeding in and about the joint for the thickening about the joint and the impairment of its motion This is an error Such damage occurs only with excessively strong traction or with massage and passive motion

Causes of Failures in Treatment of Supracondylar Fractures of the Femur Recurvation with the danger of late damage to nerves and vessels and of pressure ulcers will usually *not* be corrected if (1) the knee-angle of the Braun splint is not placed under the fracture site (fig 1997), if (2) the pulley for the longitudinal traction is placed too high (ventrally) (fig 1998 b), or if (3) excessive weights are used which irritate the gastrocnemius muscle and thereby cause the distal fragment to be pulled by it into increased recurvation

Recurvation disappears at once, as a rule, if (1) the knee-angle of the Braun splint is placed under (dorsal to) the fracture site (fig 1998 a), if (2) the pulley for the traction weight is lowered so far that it passes just over the toes (fig 1998 a) or at the level of the metatarsal heads (fig 1611), and if (3) the appropriate traction weight is used, i e, one-seventh of the body weight in strong patients and one-tenth in feeble patients or in cases of open fracture

As a surgical adviser I have seen several hundred supracondylar fractures of the femur Many of the responsible surgeons have told me that they had been simply unable in some cases to correct the recurvation In most such

cases I have found the three above-mentioned causes to be present, and I have often been able to demonstrate that recurvation could be made to disappear at once by changing the position of the splint, lowering the traction cord, and/or decreasing the traction weight

How a supracondylar fracture of the femur should not *be treated*

A 26 year old male tourist sustained a fracture of the distal third of the femur when his car skidded and crashed into a tree He was taken to a hospital and his leg placed in a gutter splint for two days Then tibial tubercle wire traction weighted with 19 Kg was applied with his limb on a Braun splint The foot end of the bed was raised only 20 cm He had such severe pain in the knee and thigh that morphine had to be given daily As he was repeatedly pulled beyond the splint by the strong traction, he was re-positioned several times a day On the tenth day a pressure ulcer half the size of a man's palm appeared dorsally at the level of the fracture site Severe pain was felt in the foot and the patient became unable extend his toes The foot, which was not itself suspended, sank into a drop foot position After two weeks, traction was reduced by 3 Kg and then by a further kilogram each day until it amounted to only 2 Kg after four weeks Finally even this traction was removed, and the patient was left without any supporting bandage for four days Then a plaster hip spica was applied Three weeks later, the pelvic part of the cast was removed and the leg portion split The leg was lifted out of the split plaster cylinder, massaged and treated with red and blue lights After ten more days the split cylinder also was removed Then daily "baking," histamine-iontophoresis, and forceful massage and energetic passive movements which proved very painful were begun After these treatments the knee always swelled severely For the peroneal nerve paralysis, electric treatment was applied and the patient received five Neuroyatren and eight strychnine injections After three months the patient was allowed up on two crutches but without weight-bearing When I saw him for the first time six months after the injury, the leg was shortened by 5 cm, the knee was severely thickened and almost completely stiff, the peroneal nerve completely paralyzed, and the foot immobile in a marked drop-foot position He could walk only with the help of two crutches (figures 2145—2150)

Within the first two days, severe shortening occurred because of the positioning of the limb in a gutter splint Severe pain and cramps were caused by the excessively-strong longitudinal traction of 19 Kg This pulled the distal fragment into increased dorsal angulation (recurvation) With the foot of the bed raised by only 20 cm, the weight of the body offered too little resistance to the strong traction and the limb was repeatedly pulled beyond the splint Therefore the central end of the distal fragment pressed upon the nerves and soft tissue dorsally until, with severe pain, a peroneal nerve paralysis and a large pressure ulcer developed The decreasing of traction weight down to 2 Kg was inexpedient, too Traction weight in all femoral fractures should insofar as possible remain unchanged and should as a rule amount to one-seventh or one-tenth of the body weight In slight shortening 1 Kg. may be added and in slight lengthening 1 Kg may be removed It was also bad to leave the patient without any supporting bandage for those four days just four weeks after the injury Removal of the plaster cast after three weeks was too early. The subsequent "polypragmacy" was at best superfluous, and the energetic passive movements were definitely harmful The injections and electric treatment for the nerve paralysis were ineffective as long as the pressure caused by the displaced fragment was not removed After open correction of the angulation, this paralysis disappeared by itself (figs 2145—2150)

Questions We Should Ask Ourselves to Avoid Failures When Treating Fractures of the Lower Third of the Femur

These questions are the same as those in the treatment of femoral fractures with continuous traction (see pages 1198, 1202 and 1207), but the following ones should be added:

1. Have I examined the color of the leg, the dorsalis pedis pulse and that behind the medial malleolus, and the motion and sensibility of the toes and foot?
2. Have I done an adequate reduction at once in case of closed fracture if the leg was pale and the dorsalis pedis pulse could not be felt?
3. Have I tried a vessel or nerve suture in case of rupture of vessels or nerves, if the other soft tissues were not damaged too much?
4. Have I amputated at once in a case of rupture of vessels and nerves in the presence of gross laceration and bruising of the other soft tissues in order to avoid severe infection and especially gas gangrene?
5. Have I positioned the knee-angle of the Braun splint under (directly dorsal to) the site of the fracture?
6. Have I lowered the traction cord to the level of the toes (fig 1991) or the metatarsal heads (fig 2011)?
7. Have I used neither too heavy nor too light traction (one-seventh of the body weight in muscular patients and one-tenth in feeble patients and in cases of open fractures) (figs 1998 a and 2011)?
8. Have I tried to reduce the frontal-plane or sagittal-plane displacement by manipulation or by strong continuous traction in supracondylar transverse fractures with a short fragment, and in oblique fractures with the fracture surfaces not facing each other (figs 2016—2021), or have I performed an open reduction and immobilized the fragments with the angulated blade-plate (fig 2025 a) or with a medullary nail (fig 2103, M N /figs 641, 642)?
9. Have I applied pads along both sides of the fracture site after manipulative reduction in order to avoid re-displacement during the patient's transport from the operating room to the station?

Treatment of Fractures of the Distal Third of the Femoral Shaft with the Transfixion Plaster Cast

The swelling in these fractures is severe The application of a plaster cast should therefore be postponed until the swelling has subsided This usually takes one or two weeks Since these fractures are prone to re-angulation, we use a transfixing wire through the distal fragment, as we do in isolated fractures of the radial shaft (see Vol I/p 780), and apply a plaster cast

After reduction has been achieved by continuous traction, the patient is placed on an extension apparatus with the hips and knees slightly flexed as in figure 2166 c Instead of applying a sling, we use a wire drilled through the central end of the distal fragment, tensioned in a tension stirrup and the whole then suspended

Fluoroscopy and *first roentgenograms* are made as mentioned on page 1395

The *plaster cast* is applied as described on pages 1214—1228 with the exception that the leg is neither abducted nor internally rotated. The plaster must be molded well round the wire. To assure a firm hold, a 6 × 6 cm. piece of plaster slab eight layers thick and incised from one edge to its center is placed round each end of the wire. When the plaster cast has set, the tension stirrup is removed from the transfixing wire. Strong set-screws (Vol. I/fig. 126) are pushed over both ends of the wire until they touch the plaster. The wire ends are then snipped off and the set-screws are covered with pieces of cellulose or small sponges so that one can find them more easily when the cast is removed. A plaster bandage is then applied so that the patient cannot get at the screws and the wire to rotate them, etc. This exact fixation of the wire is the best method of avoiding wire-track infection.

Splitting the Plaster Cast is required only when pain supervenes. This is rare if the cast is not applied until after the swelling has subsided.

Period of Immobilization. In plaster, too, union of the fracture takes 6 to 8 weeks. During this time the patient must remain in bed to avoid inflammation of the wire holes.

Exercises in plaster and *further treatment* are carried out as in patients treated with continuous traction (see p. 1207).

Operative Treatment of Fractures of the Distal Third of the Femoral Shaft

If, in exceptional cases of juxta-articular supracondylar fractures, correction of frontal-plane or sagittal-plane displacement cannot be achieved either by continuous traction or by manipulation because the fracture surface do not face each other (fig. 2005), we do open reduction. If the fracture is over 10 cm. distant from the knee joint we fix the fragments with a medullary nail (fig. 2103). In fractures closer to the joint we use an angulated blade-plate (fig. 2005 a). This procedure is better than driving the medullary nail through the knee joint as in figure 2006 a, a method we have used only in old cases.

Application of the Angulated Blade-Plate. The bone is exposed through a lateral incision in a bloodless field. To avoid angulation as in figure 2015, roentgenograms of the sound side also should be available. The blade-plate is bent exactly according to the anteroposterior roentgenogram to avoid angulation in the frontal plane, e. g., a varus as in figure 2005 a. After complete reduction of the fragments, the blade portion is driven through the cortical bone in such a way that it remains at least 2 cm. distant from the joint space. The screws fixing the plate portion to the shaft must be long enough to grasp both cortices, medial as well as lateral.

After operation the limb is placed on a Braun splint or a cushion for 3 to 4 weeks. Careful weight-bearing and appropriate exercises follow.

DIACONDYLAR FRACTURES OF THE FEMUR

Origin. They occur only with osseous or fibrous ankylosis of the knee in the decalcified bones of patients of advanced age. They are usually the results of the patients' simply stumbling on uneven ground. Our patients have all been between 40 and 70 years of age. The cause of the long-standing anky-

losis of the knee was tuberculous arthritis in five patients and a gunshot fracture in one

Type of Fracture The fracture line may traverse the femoral condyles as far as 35 mm proximal to the former joint space

Displacements do not as a rule occur

Complications do not develop, as this fracture unites within six weeks and causes no disturbances

Treatment. After the swelling has subsided, which generally takes a few days, an Unna's paste boot and a plaster cylinder (Vol III/figs 2175—2177) are applied for six weeks With this arrangement the patient can walk at once and can exercise the quadriceps by actively lifting the limb in plaster After removal of the plaster cylinder, the Unna's paste dressing may be extended up to the mid-thigh, since no folds in such a dressing need be feared about an ankylotic knee

No correction of the knee deformity should be undertaken, as in most cases it has existed for decades If a deformity of the knee is corrected in people over 40 years of age, their gait is often much worse than it was before because the joints of the ankle and foot cannot adapt themselves to the new position at that age

BICONDYLAR FRACTURES OF THE FEMUR ("Y" AND "T" FRACTURES)

Origin. Usually they occur through a fall on the flexed knee or by striking of the flexed knee against something In such cases the patella acts as a wedge forcing the condyles apart As an external sign of this mechanism, excoriations are usually seen over the patella, and every third bicondylar fracture is accompanied by a closed or open fracture of the ipsilateral patella (figs 2025, 2026) A relatively light traumatic force causes only a *fissure fracture of the femur* without dislocation (fig 2029) Powerful trauma leads to a fracture of both condyles ("Y" and "T" fractures) Still greater force or velocity causes closed (figs 2005, 2023, 2024) or open comminution of the femoral shaft with wounds of varying size over the patella or ventral side of the femur (figs 2025, 2026) One or several flexion and rotation wedges may be broken off They usually result from impact, flexion (leverage) forces and rotation forces

Displacement The condyles may be driven apart in varied degree Sometimes one condyle comes to lie proximal to the other one (fig 2025) This causes valgus or varus In severe displacement and comminution the short distal femoral fragment shows typical recurvation (figs 2005, 2023—2025)

The *clinical examination* is carried out as in fractures of the distal third of the femur (see page 1397)

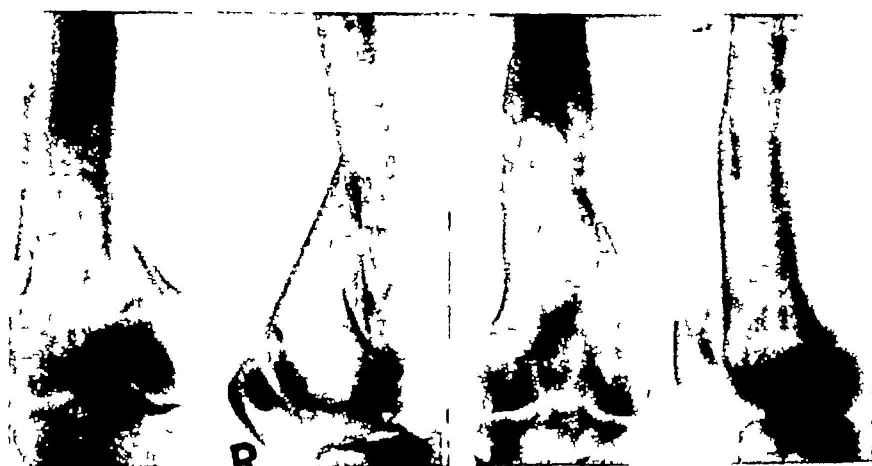
Complications Following Bicondylar Fractures of the Femur Rupture of vessels and nerves does not often occur Deformities with late arthrotic changes and impaired motion in the knee may follow if displacement is not corrected Severe infection and especially gas-gangrene have been described in open fractures



2023, September 26, 1938 2023 a, October 18, 1951

Fig 2023—Closed "Y" fracture through the distal end of the left femur and a comminuted fracture of the femoral shaft in a 49 year old female laborer who fell from the third floor of a building Tibial pin traction weighted with 9 Kg for five days was followed by supracondylar wire traction for two months She resumed her hard work as an unskilled laborer just nine months after the accident

Fig 2023 a—Check roentgenograms re figure 2023, thirteen years later Bony union with recurvation of 10° No arthrotic changes Shortening of 2 cm Normal shape and color of the knee joint Knee motion 180°—80° as against 180°—55° on the right (sound) side Muscles strong The now 62 year old woman can still work on building sites, 20 per cent permanent incapacity pension



2024, August 2, 1947 2024 a, October 24, 1951

Fig 2024—Closed supracondylar "Y" fracture of right femur with severe comminution sustained by a 37 year old locksmith who fell from a height of 3 M Tibial pin traction applied and weighted with 8 Kg Nine days later, supracondylar wire traction begun using 6 Kg for seven weeks Three and a half months after the accident he was discharged from treatment After six months he resumed his work

Fig 2024 a—Check roentgenograms re figure 2024, four years later Bony union with 10° antecurvature No arthrotic changes Limb normal shape and color, muscles strong Collateral ligaments tight Knee motion 170°–50°



2025, May 30, 1952 — 2025 a, May 18, 1954

Fig 2025—*Open* "T" fracture of femur and *open* comminuted fracture of right patella sustained by a 19 year old farmhand who fell with his motorcycle Medial and dorsal displacement of the distal fragment by the full width of the femoral shaft The medial femoral condyle lies 1 cm distal to the lateral one 12 cm long wound on the anterior aspect of knee and thigh Extensor apparatus torn A big bone splinter lay loose in the wound Pieces of cloth found in the depth of the wound Exact wound excision done under local anesthesia Excision of the severely soiled, comminuted patella Reduction and screw fixation of the medial femoral condyle The proximal fragment was put into the peripheral one and fixed with a wire loop Two drains Suture of the skin only The limb was placed on a Braun splint Tibial pin traction weighted with 7 Kg for eight weeks Treated by Dr Jorg Bohler, Linz, Austria

Fig 2025 a—Check roentgenograms re figure 2025, two years later Bony union with 5° recurvation Even joint surfaces Seven months after the injury the torn extensor apparatus was sutured Normal skin color, patella missing Muscles strong Knee motion 180°—70°



2026, September 8, 1952 — 2026 a, February 19, 1954

Fig 2026—*Open* comminuted fracture of lateral condyle and *open* fracture of shaft of left femur with apparent antecurvature of 20°, varus of 45° and lateral displacement by more than a shaft's width The antecurvature is only an apparent one, since the lateral roentgenogram was made with the knee markedly flexed A 6 cm flexion wedge of bone was found in the road at the site of accident and brought to the hospital by the ambulance personnel These injuries were sustained by a 34 year old physician when he crashed into a truck with his motorcycle Exact wound excision, reduction, screw fixation of the femoral condyles, step-shaped freshening of the femoral shaft and medullary nailing He started bearing weight after four weeks

Fig 2026 a—Check roentgenograms re figure 2026, after 17 months Bony union in good position Shortening of 3 cm Knee motion 180°—80° Treated by Dr Jorg Bohler, Linz, Austria

Avoidance of Complications Following Bicondylar Fractures of the Femur Infection can be avoided by early exact wound exision and suture of the skin alone After complete reduction and sufficient immobilization, deformities will not occure, motion of the joints will be satisfactory, and slight arthrotic changes which may develop will not cause much trouble.

Treatment of Fissure Fractures of the Femur

Fissure fractures of the femur (fig 2029) are comparatively rare Langer has found six of them among our cases

Aspiration of Blood Effusion? The usually severe blood effusion may generally be left, since it will soon be absorbed even without aspiration If it is aspirated, a compression bandage of foam rubber should be applied

Immobilization In case of pain, a plaster cylinder is applied from the hip to the ankle joint It must be split to the skin at once If there is no pain, the limb may be placed at first on a Braun splint or a cushion When the swelling has subsided, after about one week, an Unna's paste boot dressing is applied from the toes to the middle of the lower leg and a plaster cylinder from the hip to the ankle joint (Vol III/figs 2175—2177) The patient can get up with this arrangement and walk

Period of Immobilization The plaster cylinder is removed after six weeks Normal strength and motion of the leg are regained by appropriate after-treatment within two to three months

Treatment of Bicondylar Fractures of the Femur by Continuous Traction

The treatment is carried out as in supracondylar fractures of the femur (see page 1399) Care must be taken not to use excessive traction, which would markedly tense the collateral ligaments of the knee and separate the condylar fragments from one another cranially

Manual Reduction of the Separated Condyles If the condyles are separated (fig 2023), they can be pressed together manually after correction of the shortening and then treated in continuous traction

Operative Treatment of Bicondylar Fractures of the Femur

Percutaneous Transfixation of the Displaced Condyles If one condyle lies proximal to the other or is tilted, reduction is attempted by appropriate longitudinal traction with the hip and knee slightly flexed The reduced fragments are transfixed with two or three stainless wires of 2 0—2 2 mm diameter, after which the patient is kept in continuous traction The projecting wire ends are at once nipped off below skin level

If manipulative reduction fails, the fragments are exposed through a lateral or medial longitudinal incision, accurately apposed, and fixed with one or two screws A cross-bolt secured by washer and lock-nut may be employed as in figures 2025 and 2026 Further treatment is afforded with continuous traction as in an ordinary supracondylar fracture of the femur

Screwing of the Condyles Plus Medullary Nailing If, independent of the fracture of the condyles, there is an open fracture of the femoral shaft, as in figure 2026, it may be treated with a medullary nail

End Results Figures 2005 and 2023—2026 show that good results can be achieved without operation in closed fractures of the condyles as well as with operation and osteosynthesis in open fractures

MONOCONDYLAR FRACTURES OF THE FEMUR

Origin Among our 18 cases followed up by Langer, nine occurred in falls on the flexed knee and the other nine in falls from a height of at least 1 M Most of the patients had abrasions of the skin overlying the patella It is probable that in these cases one condyle is split off by the sudden impact of the patella, somewhat as in bicondylar fractures This can be seen in figure 2037 f, where the fragments are widely separated ventrally In bicondylar fractures the patella acts as a wedge in the long axis of the femur, whereas in monocondylar fractures the knee is likely in slight valgus or varus at the time of the accident Because of the physiological valgus of the knee, the lateral condyle is affected more often than is the medial condyle, viz, 13 times in our 18 cases Impact of a heavy object on the lateral or medial side of the femur is a rare cause of monocondylar fracture (fig 2027)

Types of Fractures The fracture line usually passes obliquely from the intercondyloid fossa toward and into the metaphyseal region of the femur (figs 2030, 2037 a, 2037 e)

Displacement Relatively slight trauma force causes fissure fractures without displacement In other cases, the broken-off condyle is usually displaced cranially (figs 2027, 2030, 2037 a), only rarely caudally (fig 2037 e) As the leg moves proximally, then, valgus or varus follows (fig 2027) The fragments are separated ventrally (fig 2037 f) to a varying degree Sometimes the patella remains in this ventral cleft The fractured condyle may be rotated as much as 90° round its long axis Rotation also occurs round the transverse axis of the condyle (fig 2037 a)

Recognition Fracture in the region of the knee can usually be diagnosed with ease from the positive and suggestive signs and symptoms of fracture which are as a rule present (see Vol I/p 5) It may be difficult, however, to decide which of the four condyles of the knee region is or are fractured

Roentgenograms in antero-posterior and lateral projections will establish the correct diagnosis (figs 2030—2037 f)

Complications After Monocondylar Fractures of the Femur Valgus or varus deformities with subsequent arthrotic changes, limitation of motion and pain in the knee may follow inadequate reduction or immobilization

Avoidance of Complications After Monocondylar Fractures By early recognition, accurate reduction, correct immobilization and appropriate exercises, complications can usually be avoided

Closed Reduction of Monocondylar Fractures of the Femur

Reduction is usually easy under the local anesthesia given before making the roentgenograms

Correction of Varus With the knee extended, the lower leg is abducted to normal Thus the preserved medial collateral ligament pulls the cranially-

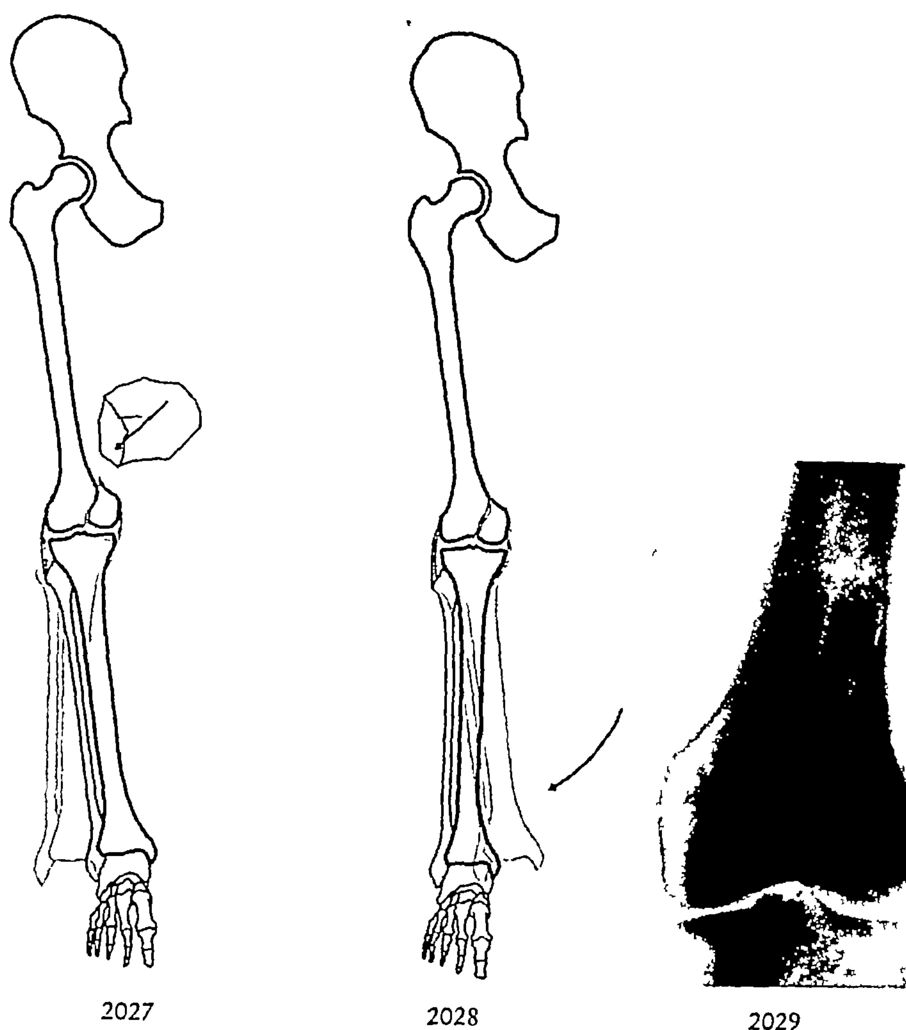


Fig 2027—Mechanism in a fracture of the medial condyle of the femur Impact of a heavy stone on the medial side of the thigh proximal to the knee joint The fragment is sheared off and displaced proximally by pressure of the tibial head The lower leg lies in the femoral axis, i e, in varus

Fig 2028—By abduction of the lower leg the proximally-displaced medial condylar fragment is pulled down by the preserved medial collateral ligament and thus reduced With the limb in this position, a plaster hip spica is applied and left for eight weeks In a fracture of the *lateral* condyle, increased *valgus* of the knee results and reduction is effected by *adduction* of the lower leg

Fig 2029—Longitudinal fracture through the distal end of the femur without displacement sustained in a fall on the flexed knee The patella, lying in the intercondyloid fossa in a flexed knee, acts as a wedge which splits the femur After withdrawal of the blood effusion, a plaster cylinder was applied and left for six weeks The patient could walk well six days after the injury Eight weeks after the injury the motion of the knee was normal After eight months the fracture line was no longer detectable in the roentgenogram

displaced medial condyle to its proper place (figs 2027, 2028) Excessive abduction should be avoided since it would separate the fragments cranially

Correction of valgus is effected by adducting the leg on a fixed femur and with the knee extended If, exceptionally, the lateral condyle is displaced

distally, as in figure 2037 e, it can be reduced by appropriate abduction of the leg (fig 2037 g, h)

Correction of Rotation If the lateral condyle is severely rotated round its long and transverse axes, as in figure 2073 a, extreme adduction is necessary to broaden the joint space and make sufficient room available for replacement of the fragment Then, by appropriate pressure with the fingers, the displaced fragment can be brought back to its proper place (fig 2037 b)



2030 August 24, 1931 2031 2032 June 7, 1954 2033

FIGS 2030, 2031 —Shearing fracture of the medial condyle with a "step" in the articular cortex (see figure 2027)

FIGS 2032, 2033 —Check roentgenograms re figures 2030 and 2031, 23 years later As manual reduction failed, the fragment was exposed through a medial longitudinal incision and fixed with three nails Knee motion 180°—70° No complaints



2034 June 16, 1933 2035 November 2, 1933 2036 2037

FIG 2034 —Fracture of the dorsal portion of the lateral condyle with dorsal displacement

FIG 2035 —Check roentgenogram re figure 2034, four and a half months later Reduction was achieved by extension of the knee Plaster cylinder for six weeks Normal motion of knee after four months

FIGS 2036, 2037 —A cup-shaped fragment sheared off the medial condyle Treated by a plaster cylinder for six weeks

Correction of Ventral Separation of the Fragments After correction of displacement in the long axis of the femur, ventral separation of the fragments can be abolished in fractures of the medial condyle be external rotation of the leg and in fractures of the lateral condyle by internal rotation of the leg



2037 a, March 17, 1944 2037 b, January 30, 1952

Fig 2037 a—Fracture of the lateral condyle of the left femur with severe displacement in a 39 year old employee who was buried by collapsing walls during an air raid Primary manual reduction, then plaster cylinder for two weeks followed by a plaster hip spica for eight weeks

Fig 2037 b—Check roentgenograms re figures 2037 a, eight years later Good position, no arthrotic changes No pain, no shortening, slight wasting (1 centimeter diminution in circumference) of the thigh Knee motion 180°—70°, tight collateral ligaments Can walk normally



2037 c, September 13, 1950 2037 d, November 22, 1950

Fig 2037 —Nine month old fracture of lateral condyle of the right femur with 12 mm cranıodorsal displacement of condylar fragment Sustained by a 21 year old miner who was hit by a mine truck on January 12, 1950 Treated *elsewhere* without reduction and with plaster cast On September 13, 1950, open reduction was performed The fragments were fixed with two screws Toe-to-groin plaster cast for ten weeks

Fig 2037 d—Check roentgenograms re figures 2037 c, three months later Bony union of fragments held together by two screws At the end of treatment, i e, five months after open reduction and one year after the accident, the knee was still swollen, motion was 165°—130°, and he walked with a slight limp

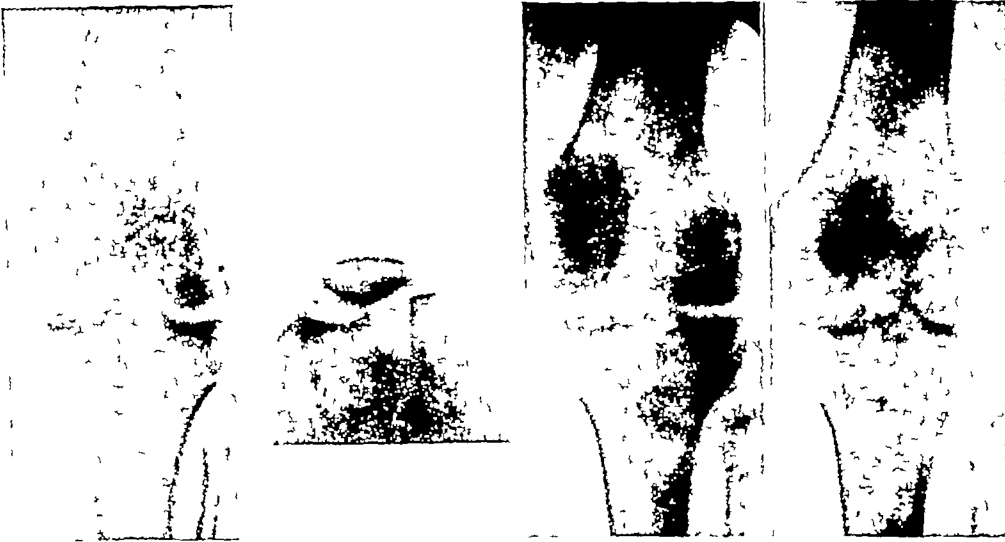
Or reduction can be acomplished by manual compression of the condyles, or in obstinate cases by means of the os calcis compression clamp (Vol I/fig 137)

Operative Reduction of Monocondylar Fractures of the Femur

Time of Operation The best time is within the first few hours following the accident, before a severe swelling has developed, provided an experienced

surgeon is present Otherwise one should wait eight to ten days and sometimes longer until the swelling has subsided and skin abrasions have healed

Operation If the above-described conservative method fails to reduce the displaced condyle because perhaps of interposition of one or more bone splinters or periosteum, the fragments should be exposed through a lateral incision in a bloodless field If the fragment still cannot accurately be reduced, it should be tilted with a hook in order that the operator may survey the fracture line and remove any interposed bone splinters or other eventual obstacles to reduction Reduction is then easy and must be performed so accurately that only a fine fissure remains visible To avoid redisplacement,



2037 h, 2037 f, May 6, 1943 2037 g, 2037 e, December 10, 1942

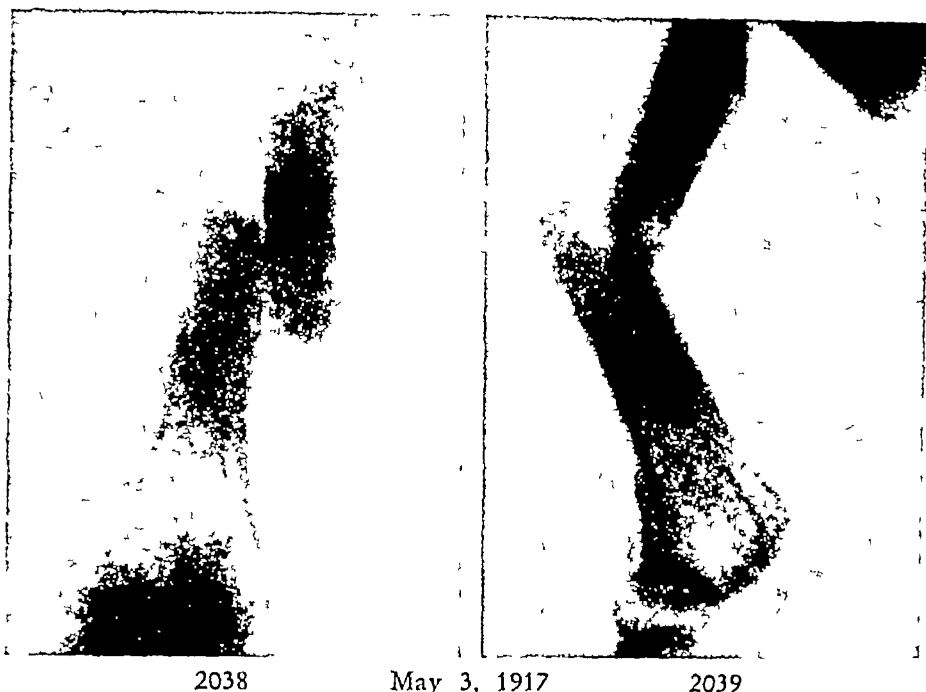
FIGS 2037 e, f —Fracture of lateral condyle of left femur in a 21 year old employee who fell off a ladder from a height of 2 M Unusual distal displacement of the fragment The fracture gapes ventrally

FIG 2037 g —Check roentgenograms re figure 2037 e, after reduction Under local anesthesia the lower leg was abducted Thus the distally displaced fragment was brought to the level of the medial condyle Then both condyles were pressed together with the calcaneal compression clamp and the separation of the fragments thus corrected

FIG 2037 h —Check roentgenograms re figures 2037 e and f, after six months Bony union across the fracture 18 months after the accident the gait was only slightly limping, the medial collateral ligament of the knee was somewhat loose, knee motion was 180°—70°

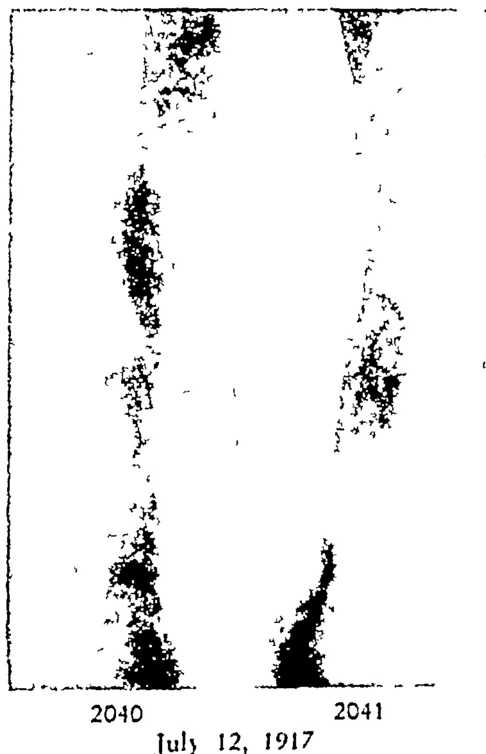
the fragment is fixed with two or three screws 6 to 8 cm long The screws must not be too short and should be at least 2 cm from the joint space (figs 2032, 2033)

First X-Ray Check After closed or open reduction, new anteroposterior and lateral roentgenograms must be made If they show the slightest displacement, i e, more than 1 mm, re-reduction must be carried out until perfectly accurate reduction is achieved



2038 May 3, 1917 2039

Figs 2038, 2039—Roentgenograms re figures 2042—2044 Double fracture of the femur with marked displacement of the fragments, before treatment In the lateral view one sees the typical recurvation angulation between the middle and distal fragments and the antecurvation angulation between the middle and proximal ones

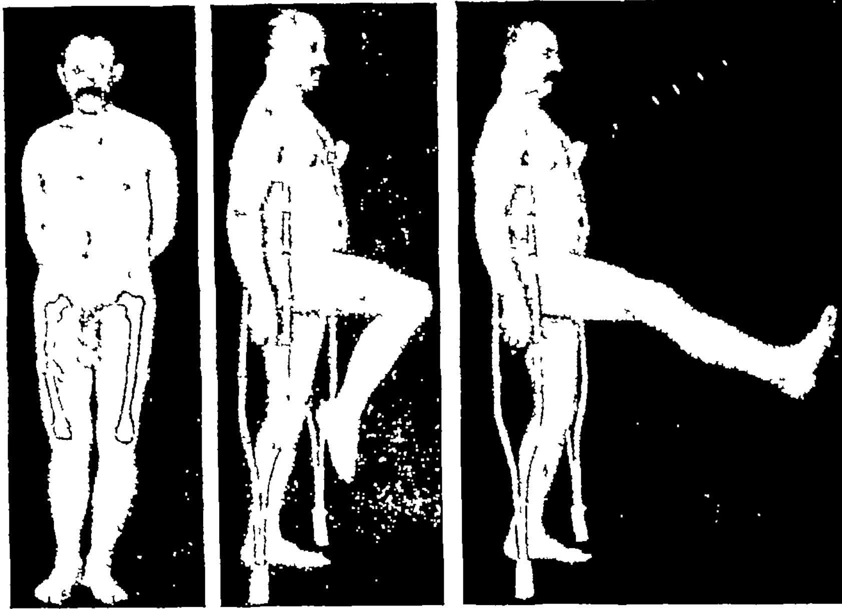


2040 2041

July 12, 1917

Fig 2040—Check roentgenogram re figure 2038, after ten weeks Union without shortening, with good callus formation The proximal and distal fragments lie in correct axis, the middle fragment is rather oblique As seen in figures 2042 2044, this displacement is not visible from the exterior and the usefulness of the leg is not impaired

Fig 2041 Check roentgenogram re figure 2039 The lateral view shows an exaggeration of the natural curve of the femur Good callus Nowadays we usually treat such double fractures with the medullary nail, as in M N (figs 133—137 and 574—581



2042 2043 2044

July 25, 1917

Figs 2042–2044 —A 45 year old man with the double fracture of the femur shown in the roentgenograms in figures 2038–2041, twelve weeks after the accident The roentgen findings are sketched on the thighs The original shortening of 6 cm has been corrected The original paralysis of the peroneal nerve has disappeared No muscle wasting or edema Free active motion of the hip and ankle joints Full active extension of knee not yet possible, though painless passive extension can be performed



2045, March 20, 1917



2046, July 26, 1917

Fig 2045 —Double fracture of left femur Varus angulation between proximal and middle fragments, valgus angulation between middle and distal fragments

Fig 2046 —Check roentgenogram re figure 2045 Union in good position without shortening Appropriate traction in abduction has corrected the varus, and the valgus has been corrected by pressure of a pad on the medial side of the more distal fracture Now we usually treat such fractures with a medullary nail

First Immobilization After closed or open reduction, a plaster cylinder from the ankle to the groin is applied (figs 2175—2177) and is immediately split completely

Second X-Ray Check After application of the first plaster cylinder, anteroposterior and lateral roentgenograms must be made

Second Immobilization After the swelling has subsided or after the operation wound has healed, i e after 8 to 10 days, an Unna's paste boot dressing is applied to the foot and lower leg and a new plaster cylinder from the ankle joint to the groin. This plaster cylinder is not to be split A plaster hip spica is rarely required

Third X-Ray Check After application of the second plaster cylinder, new antero-posterior and lateral roentgenograms should be made and thereafter should be repeated every second week

Exercises. With the plaster cylinder the patients can begin to walk about 1 Km daily during the first week and then an additional 1 Km daily each following week provided there is no pain Toes, ankle and subtalar joints must be actively moved through their full range of motion from the first day on To strengthen the thigh muscles, the limb should be repeatedly lifted into as much flexion of the hip as possible with the patient standing Apart from this, exercises of arms and legs and the whole body should be done

Period of Immobilization The plaster cylinder can usually be removed six weeks after the injury

Further check roentgenograms should be made after removal of the cast and at the time of the patient's final discharge

The *after-treatment* is carried out as in patients treated with traction (see pages 1392, 1393)

FRACTURES OF THE DORSAL PORTION OF THE FEMORAL CONDYLES

Origin. Langer, reviewing our 17 cases, has found that most of these fractures were caused by direct violence, e g the impact of a heavy object on the knee, and only a few by indirect violence, e g a fall Kostler reported 16 cases among miners in whom the knee was forced into extreme flexion by falling earth

Types of Fracture The most common type is the longitudinal fracture. Comminuted fractures are rare

Displacement Sometimes the fractures are only fissures In case there is any displacement at all, the fragment is usually displaced dorsally and proximally by 1—12 mm Lateral displacement is rare (figs 2334—2337, 2337 c—d)

Recognition. The only clinical sign is swelling caused by the blood effusion The collateral ligaments are firm, as they lie ventral to the fracture line and have remained intact

Roentgenograms Diagnosis can be made only by roentgenograms, which should be made in antero-posterior and lateral projections

Treatment of Fractures of the Dorsal Portion of the Femoral Condyles

Reduction In the case shown in figures 2034 and 2035, the fragments were reduced by extension of the knee joint In other cases, reduction has been possible by local pressure on the fragments with the joint space broadened by adduction or abduction of the lower leg

If closed reduction is not successful, the fragment should be surgically exposed and fixed with two 6—8 cm -long screws In eight of our 17 cases no reduction was required, four were reduced manually, five operatively

Roentgenograms in antero-posterior and lateral projections should be made before and after reduction and after application of an immobilizing cast

The first and second immobilization, the *exercises*, the *period of immobilization* and the *further treatment* are carried out as in monocondylar fractures of the femur (see p 1420)

61. DOUBLE FRACTURES OF THE FEMUR

Conservative Treatment If there are more than two big fragments, the treatment is the same as in simple fractures of the proximal or middle thirds of the femoral shaft (see pages 1382—1396 and figures 1604—1608) Before the introduction of medullary nailing, we used to treat all double fractures of the femur conservatively Absolutely accurate position and alignment of all fragments can usually not be achieved by pressure But it is functionally and cosmetically sufficient if the main proximal and distal fragments are in the correct axis The middle fragment may lie somewhat obliquely (figs 2038 through 2044)

When there is a fracture with three fragments presenting a varus deformity above and a valgus deformity below, the whole limb is placed in abduction to correct the varus and a pad attached to a stirrup is applied against the medial side of the more distal fracture to correct the valgus (figs 1991, 2014, 2015) As early as during World War I we achieved good position and normal usefulness of the limb (figs 2045, 2046) in this way

In treatment with continuous traction, excessive weight, causing separation of the fragments at one or the other fracture, must be strictly avoided

Operative Treatment with the Medullary Nail Since 1941 we have treated most of our closed and open double fractures of the femur with the medullary nail if there has been no shock, if the local and general conditions have been satisfactory and if absolutely everything required for such an operation has been at hand

In the case shown in M N /figs 133 and 574—581, the closed method and in the case shown in M N /figs 649—656, the open method of medullary nailing was used At present we prefer the open method under the cover of antibiotics In oblique fractures as in M N /figs 574—581, we add a wire loop for better stability This makes continuous traction treatment superfluous The patients can usually begin careful weight-bearing in the fourth week

62. FRACTURE OF BOTH FEMURS

Formerly we treated all cases of fracture of both femurs by continuous traction At present we often use medullary nailing if the local and general conditions are good

Conservative Treatment Each limb is placed on a Braun splint, as described on pages 1382—1396 and shown in figures 1604—1608, and appropriate traction is applied The lower end of the bed is raised 70 cm, since 8—10 kg

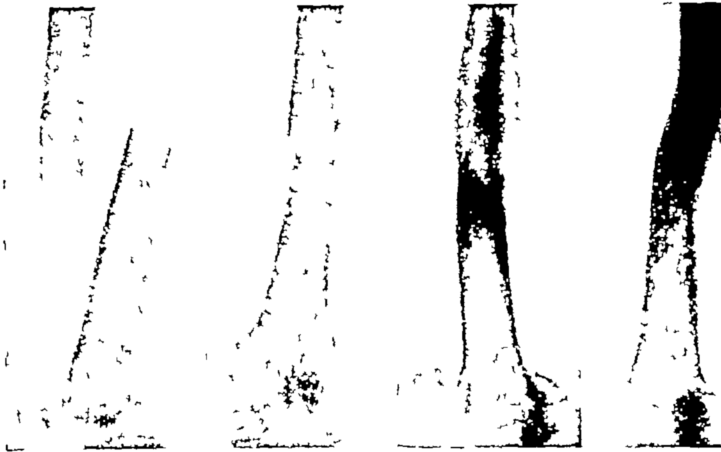


FIG 2047—A 29 year old tinsmith with fracture of both femurs caused by a fall from the fourth story of a building The right was closed, the left *open* In addition there was a fracture-dislocation of the right shoulder and a fracture of the base of the skull Patient was unconscious for eight days The wounds were immediately excised and sutured The right shoulder fracture-dislocation was reduced Each lower limb was placed on a Braun splint and tibial pin traction with 8 kg was applied to each Lower end of bed raised 50 cm

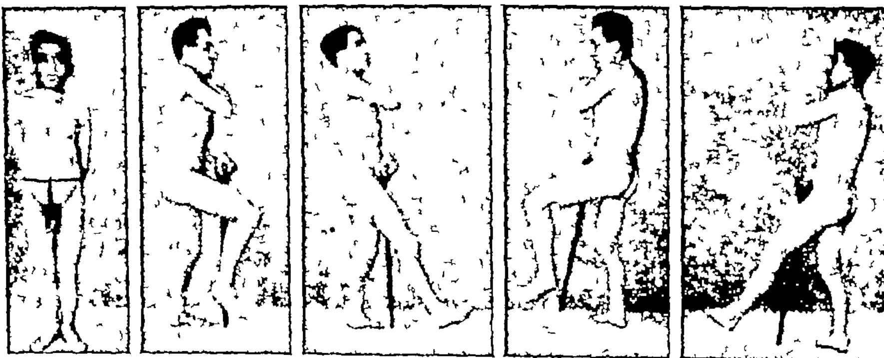
FIGS 2048—2055—Roentgenograms re figure 2047 Bilateral tibial pin traction for 28 days was followed by bilateral supracondylar pin traction for 54 more days Bilateral Unna's paste traction bandage thereafter for further 83 days Patient stayed in the hospital for 10 months and resumed work after 18 months Both femoral fractures had occurred at the junction of the middle and distal thirds Good position on both sides, no shortening Slight dragging pain felt in both thighs at night Right shoulder and the head asymptomatic As a tinsmith he is no longer able to work on the roofs but only in the workshop Now we usually treat such fractures, if there is no shock, with medullary nailing as shown in M N figs 108 122 and 608—617 The patients can then often get up as early as three to four weeks after the accident



2048, 2049, February 20, 1927 2050, 2051, March 4, 1934



2052, 2053, February 20, 1927 2054, 2055, March 4, 1934



2056—2060, March 4, 1934

Figs 2056—2060—Photographs re figures 2047—2055, seven years later No pain even when walking long distances or standing for a long time Left knee motion 180°—90°, right knee motion 175°—80°

for each limb are sometimes required in a strong patient In figure 2047 it is shown raised only 50 cm This is sometimes too little

In fracture of both femurs, distraction resulting from too strong traction and leading to delayed callus formation must be carefully avoided Delayed callus formation occurred in the man shown in figures 2048—2060 Union took 5½ months, because the attempt was made to appose the short oblique fracture surfaces accurately Too-strong traction is also the cause of a somewhat limited motion of the knee joints In fracture of both femurs, shortening of a few centimeters is insignificant if both femurs are shortened equally and if there is no angulation or rotation Lateral displacement by the full width of the shaft is of no consequence, as shown in Vol I/figs 271 through 280, and 2016—2022

Operative Treatment The patient with fracture of both femurs usually suffers from severe shock If the shock has abated under local anesthesia, warming and blood transfusion when required we sometimes carry out the medullary nailing of one femur, rarely of both, as early as on the first day In the case of an open fracture of the femur, as in figures 2099 and 2100, the wounds are accurately excised under local anesthesia Then the medullary nail is inserted as shown in figures 2087—2090 and as described in M N A drainage tube to be left for 24 hours is inserted and the wound closed. The other limb is treated with pin traction as described on pages 1383—1393 and as shown in figures 1604—1608 When, after one to three weeks, the patient has recovered from the shock of the injury and the first operation, the other femur is nailed by the closed or open method (fig 2103) This patient could get up and start walking four weeks after the accident

63. FEMORAL FRACTURES WITH CONCOMITANT INJURIES TO THE LARGE BODY CAVITIES OR TO OTHER BONES AND JOINTS

With the increase in traffic has come an increase in the number of cases of multiple severe injuries These patients usually suffer from severe shock and are often unconscious

Treatment of shock partly precedes examination and other treatment It is carried out, as described in Vol I/pp 134—138, with local anesthesia of all sites of injury, with external and internal application of warmth, and if required with blood transfusion In suspected intraperitoneal injuries, anodynes (especially morphine) must *not* be given

Examination is performed as described in Vol I/pp 8—14 The front and the back of the whole body must be examined for changes in shape or color All joints of the body should be carefully examined in order that dislocations not be overlooked

In *injuries of the skull* with unconsciousness, apart from checking the reactions of the pupils one must examine all four extremities for possible flaccid or spastic paralysis, with special regard to the possibility of an extradural hemorrhage (see Vol I pp 287—289)

In *injuries to the thorax* one must check carefully for possible open pneumothorax, tension pneumothorax and hemorrhage into the pericardium with cardiac tamponade (see Vol I/pp 473—477)

In *abdominal injuries* one searches for signs of (1) acute internal hemorrhage resulting from rupture of spleen, liver, or mesentery, (2) perforation of the gastrointestinal tract with the resulting danger of acute peritonitis, and (3) perforation of the gall bladder, bile ducts, pancreas and/or urinary bladder wih the danger of slowly-developing peritonitis Rectal examination must not be omitted (see Vol. I/pp 477—486)

In *injuries to the pelvis*, catheterization must be included in the examination of the genito-urinary tract in search of injuries to the urinary bladder, urethra and kidneys (see Vol I/pp 486—490)

Wounds cannot easily be overlooked in a careful examination

All four extremities must be carefully examined for *fractures, dislocations* and *ruptures of ligaments* Their signs are changes in shape of contour of the part, abnormal mobility and, in cases of ligamentous rupture, "springy fixation"

The greatest number of severe injuries to one lower limb which I have ever seen were in a motorcyclist who hit a truck while traveling at high speed He sustained an open comminuted fracture of the head of his right tibia, an open fracture of the patella, an open transverse fracture of the femoral shaft, a comminuted fracture of the acetabulum, and a posterior dislocation of the hip with a shearing fracture of the acetabular roof

Treatment. If, following application of local anesthesia and heat, most of the shock has abated, dislocations are reduced first under local anesthesia or in short intravenous general anesthesia, since their reduction usually takes only a few seconds or minutes

Then follows the vital *operative care of injuries to internal organs*

All *wounds* are accurately excised under local anesthesia If they are not older than six hours, the skin and nothing but the skin is sutured In concomitant injuries of the muscles a drainage tube is inserted for 24 hours (see Vol I/pp 142—190)

Fracture of the Femur and Dislocation of the Ipsilateral Hip The treatment is described on page 1115

Fractures of the Femur and the Patella In severe shock, traction (see page 1445—1454) is applied In the case of an open comminuted fracture of the patella, the patella is removed Otherwise the patella is allowed to remain Open and closed fractures of the patella are sutured later If the general condition is good, primary or delayed medullary nailing of the femur may be done

Fractures of the Femur, Tibia and Fibula In case of shock, tibial pin traction (pp 1383—1391) and os calcis pin traction, the latter weighted with 3 Kg, are applied As the traction weight for the tibia and fibula acts partly also on the femur, traction for the femur must be limited to one-tenth of the body weight

From the use of excessive weights we have seen severe disturbances For example, a patient was admitted who had os calcis wire traction weighted with 15 Kg for twelve weeks The result was non-union of femur, tibia and fibula.



2061 September 1, 1928 2062 2063 December 14, 1928 2064



2065, April 19, 1937

Figs 2061, 2062 —*Open* separation of the epiphysis of the distal end of the femur sustained by a 16 year old tailor's apprentice who, while riding a motorcycle, was hit by an automobile Atypical displacement with a mediodorsal flexion wedge and severe dorsal displacement of the distal fragment Skin and joint were torn wide open and the wound was dirty

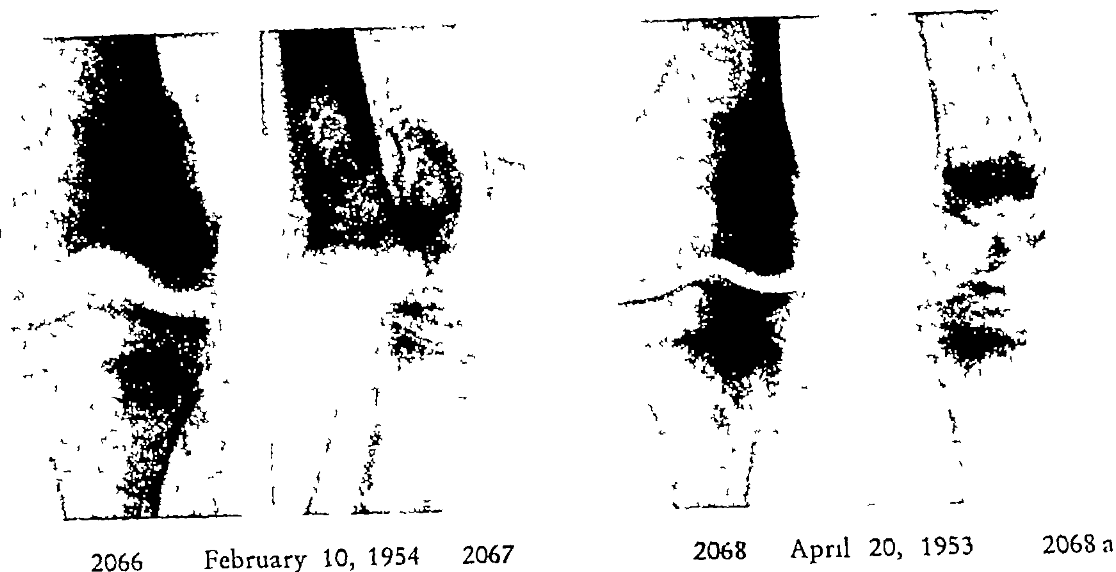
Figs 2063, 2064 – Check roentgenograms re figures 2061 and 2062, fourteen weeks later After accurate wound excision, insertion of a drainage tube and suture of the skin only, the fracture was reduced with strong tibial pin traction Uneventful healing of the wound, bony union after six weeks The patient was fit for work after fourteen weeks Knee joint capable of full active motion The pin hole can be seen in the tibia

Figs 2065 Photographs re figures 2061—2064, eight and a half years later There is normal shape, strength and motion of the injured limb

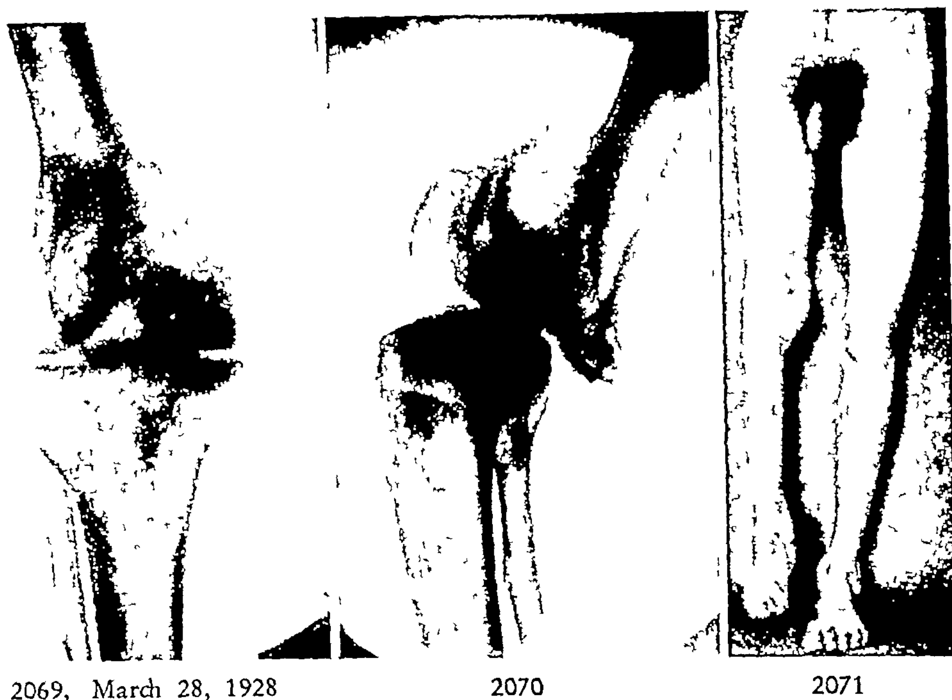
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Figs 2066, 2067 —Apparently pure separation of the distal femoral epiphysis without a metaphyseal wedge, sustained by a 14 year old fisher boy who jumped off a moving streetcar Treated by Dr Paraskevas, Athens, Greece, by strong manual traction on the flexed lower leg and countertraction on the thigh Plaster cast for six weeks

Figs 2068, 2069 —Check roentgenograms re figures 2066 and 2067, ten months later Union in very good position Full range of active motion in the knee Patient can use this limb normally Asymptomatic



2066 February 10, 1954 2067 2068 April 20, 1953 2068 a



2069, March 28, 1928 2070 2071

FIGS 2069, 2070 —Roentgenograms of a 10 year old separation of the distal femoral epiphysis Typical anterior displacement of the distal fragment The distal fragment is rotated through 90°, with marked displacement cranially and ventrally The distal posterior corner of the shaft presses on the nerves and vessels in the popliteal space (fig 2071)

FIG 2071 —Photograph re figures 2069, 2070 Ischemic muscle contracture with loss of the terminal segments of the toes following an old unreduced displacement of the distal femoral epiphysis Patient had been treated by adhesive plaster traction in a straight-knee position without previous reduction of the deformity By this hyperextension, pressure on the popliteal vessels was caused with disastrous results If no treatment had been used the knee would have remained flexed and trophic disturbances would not have followed

If there is no shock, primary or delayed medullary nailing of the femur, and in exceptional cases also of the tibia, may be performed (M N/figs 133 through 142)

In *fractures of the femur and the ankle* the malleolar fracture is treated first by reduction and plaster cast The cast must at once be split completely. The femur is treated in traction (see page 1383—1391 and figure 2009) or with medullary nailing

In *fractures of the femur and the os calcis*, if the femur is to be treated in traction, the os calcis fracture is reduced first and traction of 3 Kg is put on the os calcis pin If the femur is to be nailed, the nailing is done first and the reduction of the os calcis with institution of pin traction follows

In *fractures of the femur and fractures or dislocations of the tarsal bones other than os calcis*, the tarsal fractures are reduced first The femur can then be treated with traction or, if the patient is in good general condition, with a medullary nail either at once or later

In fractures of the femur and the vertebral column the femur can be operated on first and fixed with a medullary nail provided the patient's general condition is good The vertebral fracture is then reduced later

If medullary nailing cannot be performed because of the patient's poor general condition, the vertebral fracture is reduced first and then traction used for the femur

64. SEPARATION OF THE DISTAL FEMORAL EPIPHYSIS

Origin. Formerly this injury was most often seen resulting from a leg's having been caught between the spokes of a rolling wheel Nowadays football, the motorcycle and the automobile are the most common causes

Age Distribution In our 18 cases, Langer found this injury occurring between the tenth and twentieth years of age, fourteen of the patients being between the ages of fourteen and eighteen It is also sometimes seen unilaterally or even bilaterally in newborn babies as the result of obstetrical maneuvers

Types of Fractures Pure separation of the epiphysis is rare (figs 2066 through 2068 a) Langer found only one case amongst our 18 cases A wedge of varying size is usually broken off the metaphysis (fig 2061) In rare cases the displaced epiphysis is split in the sagittal plane One part may be displaced alone (figs 2701 a, b) Comminution of a part of the epiphysis and incomplete reduction may lead to disturbance of growth (figs 2171 d—2171 h)

Displacement. The epiphysis may be separated but with a barely perceptible displacement Then two or three weeks later the roentgenograms show extensive periosteal callus In our cases, posterior displacement (figs 2061—2065) was more frequent than anterior displacement (figs 2066 through 2071), and simultaneous lateral displacement was more frequent than medial displacement

Complications Following Separation of the Distal Femoral Epiphysis Infection following open separation of the epiphysis has often been reported

Anterior dislocation may cause injuries to vessels or nerves followed by gangrene or ischemic disturbances (figs 2069—2071) Angulation deformities with limited joint motion and arthrotic changes may result from incomplete reduction or from disturbed growth (figs 2171 d—h)

Avoidance of Complications Infection after open separation of the epiphysis can be avoided by accurate wound excision, satisfactory reduction of the separation and suture of the *skin only* (figs 2061—2065) Circulatory disturbances due to pressure of the proximal fragment on vessels and nerves can be avoided if reduction is carried out in time Growth disturbance following longitudinal splitting of the epiphysis cannot always be avoided (figs 2071 d—h)

The **recognition** of separation of the distal femoral epiphysis is sometimes difficult With lateral displacement and angulation it has been mistaken for a dislocation of the knee, since no abnormal mobility could be elicited

Roentgenograms made in anteroposterior and lateral projections will establish the correct diagnosis In cases with little displacement, as in figure 2071 c, comparison views of the sound side should be made in order that the amount of displacement can be accurately determined

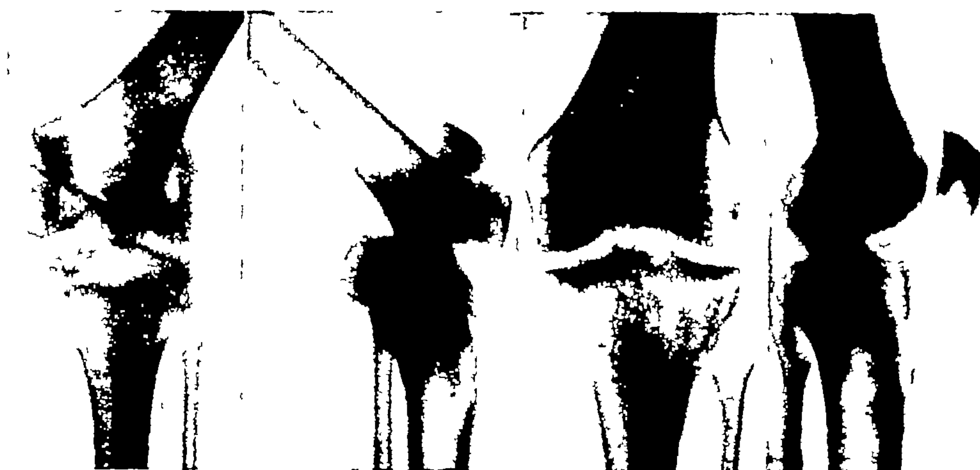
Treatment. As with the traumatic epiphysiolysis in most other bones, reduction of the epiphyseal separation in the distal end of the femur can usually be achieved only by manipulation and not by continuous traction General anesthesia is as a rule required First, the shortening must be overcome by strong longitudinal traction If lateral displacement (in the frontal plane, as in figure 2061) does not disappear following this, it can be corrected by appropriate pressure and counter-pressure Displacement in the sagittal plane should be corrected only after correction of the shortening and the lateral displacement in the frontal plane

Reduction of the ventrally displaced epiphysis is achieved by strong longitudinal traction on the partially-flexed lower leg As soon as shortening and lateral displacement have been corrected, ventral traction is exerted on the femur just proximal to the knee joint and the knee is flexed to a right angle while longitudinal traction in the long axis of the lower leg is maintained One usually feels a soft click at the instant the displacement is reduced

Dorsal displacement also is corrected by strong longitudinal traction, the knee being at first slightly flexed and the hyperextended (figs 2061—2065) This, too, is done after any lateral displacement has been corrected

Lateral displacement and angulation in the frontal plane (fig 2061) can usually be corrected by manual pressure and counterpressure during longitudinal traction and after shortening has been overcome Conditions are the same as those in epiphyseal separation in the distal end of the humerus (see Vol I/pp 651—656) Thus forceful reduction over a wooden wedge or with the Phelps-Gocht apparatus (Vol I/fig 138), as used formerly, is rarely necessary

Reduction of Angulation in the Frontal Plane Alone If there is only a varus or valgus angulation, it can be corrected by strong longitudinal traction and angulation of the lower leg towards the opposite side If



2071 a, September 29, 1943 | 2071 b, May 29, 1954

Fig. 2071 a.—Separation of the left distal femoral epiphysis with dorsolateral displacement. The lateral portion of the epiphysis is separated from the medial portion by a longitudinal fissure and is dislocated ventrolaterally. Sustained by a 15 year old waiter's apprentice who jumped off a moving streetcar. Reduction in general anesthesia, then plaster hip spica for eight weeks. He could walk after three weeks.

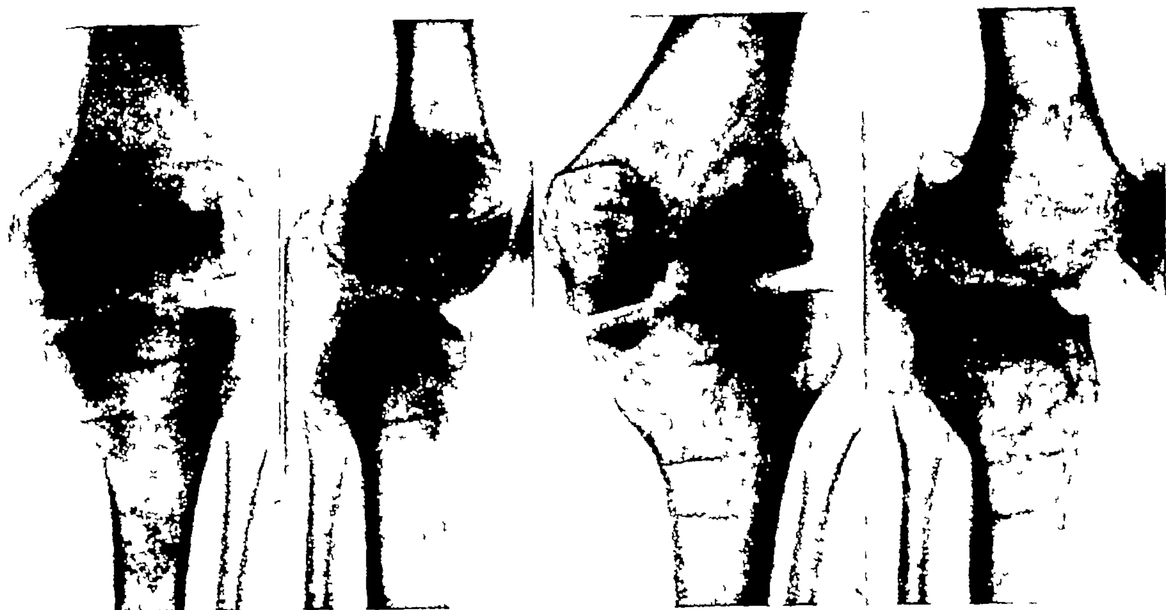
Fig. 2071 b.—Check roentgenograms re figure 2071 a, eleven years later. Fragments have united in excellent position. No arthrotic changes. Clinically, normal color and shape of the knee. Knee motion 180°—45°. The collateral ligaments were firm in full extension, slightly loose in flexion. No complaints.



2071 c, June 10, 1944 | 2071 d, April 14, 1947

Fig. 2071 c. Comminuted fracture of the lateral portion of the distal epiphysis of the left femur with separation and lateral displacement in an 11 year old schoolboy who was buried by rubble during an air raid. Treated only with a plaster cylinder which was removed after only four weeks for nonmedical reasons.

Fig. 2071 d. Check roentgenograms re figure 2071 c, three years later. The epiphyseal line has fused laterally and the lateral condyle shows arrested growth. Thus a valgus of 20° has resulted. *Closed* supracondylar osteotomy, correction of valgus, then plaster hip spica for six weeks.



2071 e, June 2, 1947 1071 f, May 19, 1953

Fig 2071 e—Check roentgenograms re figure 2071 d, seven weeks after *closed* supracondylar osteotomy Varus of 5⁰ instead of the former valgus of 20⁰

Fig 2071 f—Check roentgenograms re figure 2071 e, six years later Further relative arrest in the growth of the lateral condyle A valgus angulation of 20⁰ has redeveloped



2071 g, June 29, 1953 2071 h, May 23, 1954

Fig 2071 g—Check roentgenograms re figure 2071 f, after *open* supracondylar osteotomy The position is maintained by two crossed wires drilled through the bones Wires were removed after application of the plaster hip spica

Fig 2071 h—Check roentgenograms re figure 2071 f, one year later and ten years after the accident Thigh and lower leg in same axis (i e, varus) Oblique joint space Clinically slight varus Knee motion 180⁰—120⁰

this cannot be achieved manually, the convex side of the angulation is placed on a padded wooden wedge and the limb is bent over the wedge

Delayed Reduction of Epiphysiolysis A 12 day old epiphysiolysis could be reduced after it had been mobilized over a wedge A 3 month old epiphysiolysis was mobilized and reduced operatively

If an unreduced case of epiphysiolysis with severe ventral displacement of the distal fragment is treated by continuous traction with the knee extended, the dorsal margin of the proximal fragment will press upon the popliteal vessels and nerves Ischemic disturbances or gangrene of the leg may follow In 1928 I had the opportunity to see such a case (figs 2069—2071)

Check Roentgenograms Post-reduction roentgenograms are made in antero-posterior and lateral planes They usually show good position If not, reduction and roentgenograms must be repeated

Immobilization. It can be achieved in pin traction as in fractures of the femoral shaft (see pages 1383—1391 and figures 1604—1608) or in a toe-to-groin plaster cast with the knee extended *This plaster cast must at once be split down to the skin without leaving one single thread intact*

Second Check Roentgenograms After application of the plaster, new roentgenograms must be made in both main planes In traction treatment the first check roentgenograms are made after 24 hours

Application of the Walking Plaster When the swelling of the thigh has subsided in traction or in plaster after 8 to 12 days, a walking plaster cast, as described on pages 1393—1396, can be applied Roentgenograms are made just before and just after application of the plaster cast

Further Treatment In Traction The limb may also be left in traction until union has occurred

Treatment of Epiphysiolysis in the Lower End of the Femur The limb is placed on a Braun splint or a cushion for two to four days until the swelling has subsided Then an Unna's paste boot dressing and a plaster cylinder (Vol III/figs 2175—2177) are applied

Period of Immobilization After good reduction the separated epiphysis unites within six to eight weeks depending on the degree of original displacement In epiphysiolysis essentially without displacement the plaster cylinder can be removed after only four weeks

Check Roentgenograms In traction as well as in plaster, antero-posterior and lateral roentgenograms are made after eight days and then every second week

Special *follow-up treatment* is not necessary, since mobility and strength usually return within a few weeks after good reduction

Treatment of Growth Disturbance Following Separation of the Distal Femoral Epiphysis Premature fusion across one portion of the epiphyseal line following separation of the epiphysis with a longitudinal cleavage fracture of the epiphysis leads to varus or valgus deformity (figs 2071 d and f) We have observed such disturbed growth only once amongst our eighteen cases It can be corrected by supracondylar closed (fig 2071 e) or open osteotomy (fig 2071 f) Stapling across the epiphyseal plate (epiphysiodesis) according to Blount can also be done

Case History An 11 year old boy was buried by rubble during an air-raid on June 11, 1944 He sustained a separation of the distal epiphysis of his left femur with little lateral displacement A sagittal longitudinal cleavage fracture passed through the center of the lateral condyle The lateral portion of the epiphysis was compressed (figure 2071 c) As the severity of the injury was not recognized, no attempt at reduction was made but only a plaster cylinder was applied Because of war-time conditions, the boy was evacuated from Vienna a few days later The plaster cylinder was removed after four weeks

If proper importance has been attached to the injury, reduction might have been performed by strong adduction of the lower leg and the lateral portion of the epiphyseal space might have been expanded On the basis of the findings as shown in figure 2071 a and *from experience* with other similar cases, we feel that premature fusion across part of the epiphyseal line would probably have been avoided by this

When we saw the patient again three years later on April 14, 1947, he had a valgus deformity of 20° (figure *2071* d) An attempt was made to correct this by a supracondylar osteotomy The 5° of varus achieved was, however, too little (figure 2071 e) During the period of growth one should always provide a marked overcorrection When he came in again on May 19, 1953, i e, nine years after the accident, he again showed a valgus deformity of *20°* The joint space of *the* knee was oblique, since a *compensatory varus had developed* in the proximal end of the tibia (figure 2071 f) An open supracondylar osteotomy was performed and femur and tibia were brought into the same axis (figure 2071 g) The outward appearance one year *later* distinctly shows varus deformity, as the physiologic valgus of 10° is missing The joint space of the knee is oblique, and arthrotic changes will probably develop later on Knee motion 180° to 120°

This case history shows that even slight displacement should be corrected immediately after the injury, especially if a sagittal fracture line crosses the epiphyseal plate If growth is disturbed, an over-correction of from 15° to 20° should be accomplished by osteotomy during the period of growth This overcorrection will of course disappear again later No overcorrection should be accomplished after fusion across the whole epiphyseal line or after the end of the growing period (fig 2071 g, h)

Questions We Should Ask Ourselves to Avoid Failures When Treating Separation of the Distal Femoral Epiphysis

1 Have I, in the case of pressure on vessels and nerves, reduced the displacement at once to avoid ischemic disturbances (figs 2069—2071)?
2 Have I excised the wound at once in open epiphysiolysis and sutured the skin if the injury was not older than six hours, in order to avoid wound infection, and have I *then* done a good reduction (figs 2061 through 2065)?
3 Have I reduced accurately and immediately any epiphysiolysis with sagittal longitudinal cleavage in order to avoid growth disturbance and consequent deformity (figs 2071 c—h)?
4 Have I made comparison roentgenograms of the sound side in cases of slight displacement, as in figure 2071 c?
5 Have I, at the time of reduction, overcome *the* shortening first by strong longitudinal traction and only then corrected the displacement in the sagittal plane by appropriate pressure and counterpressure?
6 Have I split any plaster cast applied within the first few hours after the injury *at once* and right down to the skin to avoid circulatory disturbances?

7 Have I made new roentgenograms after reduction?
8 Have I made new roentgenograms both before and after application of the plaster cast?
9 Have I *achieved* overcorrection after supracondylar closed or open osteotomy when operating for growth disturbances *before* fusion across the epiphyseal plate?
10 Have I *avoided* overcorrection when operating for correction of growth disturbances *after* fusion across the epiphyseal plate?

65. FRACTURE OF THE FEMUR IN CHILDREN

Origin and Types of Fracture Femoral fractures may occur as early as during delivery when with a breech presentation a leg is brought down These are usually transverse fractures In older children, torsion fractures are often seen in the proximal, middle or distal thirds (Vol I/figs 261—268)

Displacements are the same as in adults

Treatment by Traction Bandage In children under four years of age the limb may be suspended vertically by means of adhesive plaster (Vol I/figs 695 and 1608) or Unna's paste traction (fig 2072) with the knee extended. Round the adhesive tape as well as round the Unna's paste dressing is wrapped a plaster bandage in order to avoid slipping of the traction bandage The traction band is kept apart distal to the sole of the foot by a 6 × 6 cm wooden spreader (Vol I/figs 148 and 695) to protect the soft tissue over the malleoli from pressure Enough weight is used to raise the buttock of the affected side from the bed The fracture unites within three to four weeks

Treatment by Wire Traction In older children skeletal traction is used as in adults but with a wire rather than a Steinmann pin (see pages 1383—1391 and figures 1604—1608)

Treatment in Plaster In babies and infants, "plaster pants" may be applied with the hips and knees flexed to right angles Both are included, but the feet are left free A broad piece of felt is laid round pelvis and abdomen and secured there with a gauze bandage Two plaster bandages are then put over this Hip and knee on the injured side are then flexed to right angles and the fracture is reduced by strong traction A dorsal plaster slab is placed from the pelvis to the ankle and is fixed with a gauze bandage A circular plaster bandage is put round on top of it To avoid breakage of the plaster in the hip region, plaster slabs are added for support anteriorly and laterally When the plaster has been applied to the injured limb, the sound limb is dealt with in the same way (figs 2073—2075) The children can sit and lie comfortably with this plaster cast and can be easily cared for and even suckled If the plaster cast is applied on the first day *it must at once be split on the injured side right down to the skin* When the swelling of the leg has subsided after one week, the split cast is removed and a closed plaster cast is applied in the same way

Operative Treatment is never necessary in children, since the fracture unites within three to five weeks in traction or in plaster *provided* distraction from excessive traction is avoided

Period of Immobilization In very young children the fracture unites within three weeks, in older children within four to five weeks

Influence of the Fracture On Growth Shortening of up to 2 cm is of no concern The fracture stimulates growth of the bone and the shortening disappears after some months If the fracture has been reduced so well that union occurs without shortening, a lengthening of 1 to 2 cm is often observed after 2 to 3 months This lengthening, too, is unimportant, as it also disappears in a few months

Angulation in the shaft region up to 30° usually disappears, but juxta-articular angulation must be corrected to avoid deformities (Vol I/figs 269 and 270) In tiny babies one sees, in fact, that angulations of even 90° may have disappeared after several months

66. FRACTURE OF THE FEMORAL SHAFT DUE TO ABNORMALITY OF THE BONE

Origin. Pathological changes may result from many different processes, e g (1) Disturbed balance of hormones and vitamins This leads to osteoporosis, osteomalacia, osteogenesis imperfecta, osteopathia fibrosa cystica localisata and generalisata (Recklinghausen), (2) Benign bone tumor (fibroma, enchondroma), (3) Malignant bone tumor (sarcoma, carcinoma), (4) Metastatic tumor following primary malignancy elsewhere (carcinoma, sarcoma, hypernephroma), (5) Infectious disease (osteomyelitis, tuberculosis, lues, etc), (6) Neuropathy (tabes, syringomyelia, etc), (7) Paralysis (spinal cord transection, apoplexy, poliomyelitis), (8) Disease of unknown origin (e g , Paget's disease and numerous rare conditions), and (9) Large vascular tumor causing pressure erosion of the bone

Types of Fracture Most of these fractures are transverse fractures through the weakened parts of the bones, especially through bone cysts (figs 2078 a, 2078 e) The fractures in Paget's disease have even fracture surfaces without any dentation, as if the bone had been cut with a knife In addition, one often sees one or more transverse fissures along the convex side of the curved bone In paralysis, torsion fractures are common (M N /figs 582—589)

Displacements are the same as in normal bones If a bone is broken by an insignificant trauma force, one speaks of a *pathologic fracture* If the fracture occurs without any real trauma at all, e g , when the patient turns over in bed or pulls on his socks, as in the case shown in figure 2078 a, it is in addition spoken of as a *spontaneous fracture*

The *recognition* of the fracture is usually a simple matter Diagnosis of the original disease, however, may be very difficult If a patient has been operated on for carcinoma of the breast and then later her femur breaks through, say, the proximal third as a result of no real violence, then we should think of a bone metastasis Roentgenograms will confirm the diagnosis The symptoms of the primary tumor often lag rather far behind the fracture of the bone, and that primary tumor may remain undiscovered until the end of the patient's life In benign and malignant cysts, "rheumatic" pain usually precedes the fracture for weeks or even months

Complications Following Femoral Fractures Due to Abnormality of the Bone Severe deformities and sometimes non-union may result from inadequate treatment or in the absence of treatment

Avoidance of Complications. Many surgeons believe that nothing should be done for those fractures occurring in diseased bone whether the disease be malignant or benign Certainly, at least in the case of the benign diseases,

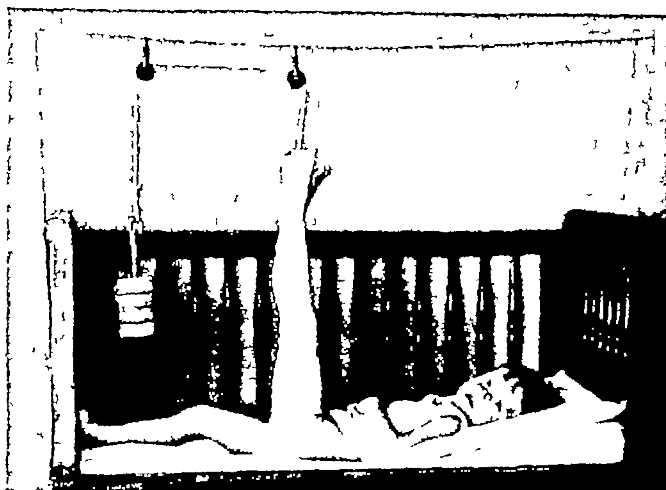


FIG 2072—Treatment of fractured femur in a child The limb is vertically suspended in adhesive plaster traction The weights are arranged in such a way that they cannot fall on the child

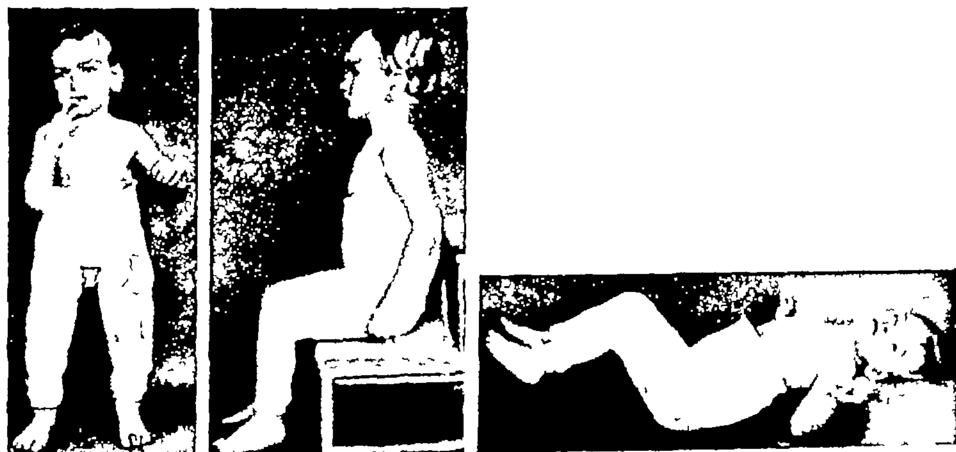
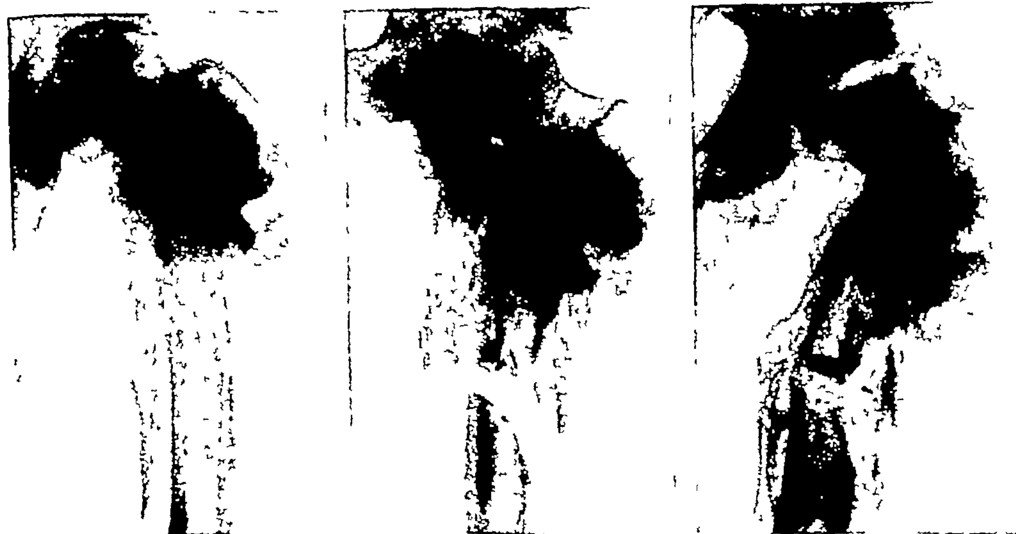


FIG 2073—After reduction, "plaster pants" are applied with the hips and knees flexed The ankle joints may be left free Both lower limbs must of course be included in the cast

this is wrong, since essentially normal form of the limb and its full usefulness can often be achieved by adequate treatment And even in malignant tumors, freedom from pain can be achieved by, for example, traction and temporary usefulness of the limb by appropriate osteosynthesis

Treatment depends on the original disease and the patient's general condition Formerly we treated all pathologic and spontaneous fractures by

traction until the fracture was healed or the patient died from the original disease At present we excise malignant primary bone tumors and metastases and unite the fragments by a medullary nail, with or without implantation of a new bone graft Ehalt,[1] in a very good paper, insists that these major operations should be performed only if a blood bank and a bone bank are at the surgeon's disposal In metastases from carcinoma of the prostate, hormones are given to the patient while he is in traction In hypernephroma, the diseased kidney is removed if conditions therefore are favorable In osteomyelitis, tuberculosis and lues, antibiotics are given in addition



2076, January 21, 1927 2077, March 2, 1927 2078, October 23, 1929

FIG 2076 —Subtrochanteric fracture of the femur caused by the impact of a heavy iron rod on the thigh of a 40 year old man with beginning tabes Healed in marked varus and internal rotation Shortening of 4 cm Exuberant callus with extensive periosteal ossification

FIG 2077 —Check roentgenograms re figure 2076, after osteotomy and correction of varus and rotation The fragments gape, a sign of excessive traction

FIG 2078 —Check roentgenograms re figure 2076, after $2^3/_4$ years The man walked well for two years, then started to limp Osteotomy site united well Hip joint shows the signs of tabetic arthropathy

Treatment of Pathological Fractures of the Femur in Continuous Traction In cachexy, and in osteomyelitis and tuberculosis, treatment of the femoral fracture is best carried out in traction (see pages 1383—1391 and figures 1604 through 1608) Since the muscles have often become very weak by previous long and severe disease, and since parts of the bone are sometimes missing because of the disease, we must take special care to avoid distraction Only a fifteenth part of the body weight should be applied at the beginning, i e, only 4 Kg for a body weight of 60 Kg Often even less than this must be used

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[1] Ehalt, W Die pathologischen Knochenbruche Hefte zur Unfallheilkunde, Heft *47* 202—207, 1953



2078 a, February 14, 1953 — 2078 b, March 12, 1953 — 2078 c, — 2078 d December 12, 1953

FIG 2078 a—Pathologic spontaneous fracture of right femur through a hypernephroma metastasis Sustained by an 82 year old diabetic dental surgeon when he was putting on his socks Transverse en bloc excision of a 7 cm long piece of the femur, then medullary nailing Patient could get up three weeks after the operation without any external support

FIG 2078 b—Check roentgenograms re figure 2078 a, four weeks later A prominent bulge has developed medially

FIGS 2078 c, d—Check roentgenograms re figure 2078 a, ten months later The fracture site severely broadened and cystic, but more dense Patient can walk well and feels no pain



2078 e, May 5, 1927 — 2078 f, June 16, 1927 — 2078 g, August 4, 1927 — 2078 h, January 20, 1928

FIG 2078 e—Subtrochanteric fracture through what was thought to be a benign cyst of right femur On excision it proved to be a metastasis from a hypernephroma Sustained by a 25 year old sewer worker who fell off his bicycle Traction for six weeks, plaster hip spica for four more weeks

FIG 2078 f—Check roentgenogram re figure 2078 e, six weeks later Good position of fragments Good callus formation medially Tumor has grown in size

FIG 2078 g Check roentgenogram re figure 2078 e, three months later Destruction of bone much progressed Coxa vara has developed

FIG 2078 h Check roentgenogram re figure 2078 e, eight months later The whole trochanteric region has disappeared Only a slight shadow of the femoral head is visible Patient died from



2078 i, May 4, 1954 2078 j, May 25, 1954 2078 k,

FIG 2078 i—Smooth transverse fracture in the middle third of the right femoral shaft and fissure fracture in the proximal third Two cm distal to the fresh transverse fracture there is a healed fracture through an area of Paget's disease The healed fracture had been sustained by this 61 year old farmer in a fall from a hay wagon eleven months previously He was treated *elsewhere* in traction for $4^1/_2$ months and in a plaster hip spica for another $4^1/_2$ months He then started walking with crutches The fresh transverse fracture follows another fall Treatment wedge osteotomy was done in the middle of the proximal fragment, the curved bone was brought into line, a medullary nail was inserted and a longitudinal wire loop was placed through both fracture ends to avoid rotation

FIGS 2078 j, k—Check roentgenograms re figure 2078 h, three weeks later The bone is straight and so stabilized by the medullary nail that the patient can already walk



2079, May 18, 1935 2080, February 11, 1936

FIG 2079—Subtrochanteric fracture sustained by a 56 year old woman with Paget's disease *Smooth* transverse fracture such as never occurs in a normal bone Treatment by traction for ten weeks

FIG 2080—Check roentgenograms re figure 2079, nine months later The fragments have united in good position with strong callus She walks as well as before the accident

Treatment of Pathologic Fractures of the Femur by Plaster Cast I osteomyelitis or tuberculosis there are signs of severe inflammation and l temperature, it is sometimes expedient to apply a thoracopelvic plaster spica (see pages 1393—1396) instead of traction The plaster cast r usually remain many months until the bone has become capable of wei bearing Penicillin, Streptomycin and other antibiotics are administered

Treatment of Benign Cysts by Medullary Nailing After fractures thro them, benign cysts sometimes become smaller or disappear When this not happen, we used to curette out the cyst and fill the defect with autogen bone chips To avoid growth disturbance, near epiphyseal synchondroses c must be taken not to injure the growing cartilage of the epiphyseal plate present we treat these cases by closed medullary nailing. M N /figs 784— show a case of osteopathia fibrosa cystica localisata in which not only the fracture heal firmly after closed medullary nailing, but the c spontaneously filled with normal bone The causes of this are described M N /pp 243—245 If a cyst lies in the trochanter, a three-flanged i is used in the femoral neck and a plate with screws for the femur (figs 18 1980 c, 2130)

Treatment of Osteogenesis Imperfecta by Medullary Nailing The fragil of bone usually disappears in this disease with the end of the growth peri If a femur breaks, medullary nailing is the best means of treatment Then the medullary nail is left in place a new fracture can be avoided As other femur often breaks, too, it is expedient to insert a medullary nail in it also as a prophylactic measure If other bones break they are treated the usual way Callus usually forms readily With this use of the medulla nail the severe femoral deformities which are common in this disease aft fractures can be avoided

Excision of Tumor Metastases Plus Medullary Nailing If the gene condition is at least fair and cachexy not too severe, the site of fracture exposed and the metastatic lesion excised en bloc Then a medullary nail inserted (figs. 2087—2090) The fragments are secured against rotation l a longitudinal wire loop (figs 2078 a—d) The shortening caused by t resection is of no account in such cases, since because of their general conditio most of these patients can no longer work and, in fact, usually die from oth metastases after a few months or a few years After operation the limb placed on a Braun splint or cushion without any other support The patie can usually try careful weight-bearing three weeks later

Treatment of Femoral Fractures Through Hypernephroma Metastases b Excision and Medullary Nailing If the patient is in satisfactory gener condition, the metastasis is resected and medullary nailing is done (figs 208 through 2090) Without excision the bone would be completely destroyed b the osteoclastic type of metastasis (figs 2078 e—h) In the osteoblastic typ we have seen the bone unite in pin traction within eight weeks withou apparent further growth of the tumor

Hormone Treatment of Pathologic Fractures of the Femur in Metastati Carcinoma of the Prostate Of all types of carcinoma, that of the prostat

with its metastases is the only one in which hormone treatment seems to have marked effect It is therefore not necessary to excise the bone metastases in this tumor These fractures are treated by the usual pin or wire traction (see pages 1383—1391 and figures 1604—1608) and with the appropriate hormones The fracture usually unites within a normal period of time and the metastases as a rule disappear temporarily

Treatment of Femoral Fractures Through Areas of Sarcoma by Excision and Medullary Nailing The histologic diagnosis, especially from the frozen section, is often very difficult, and we have not rarely received negative biopsy reports in positive cases This is in part explained by the fact that one sometimes fails to reach the tumor tissue in taking the material for biopsy

It is now our practice to send our specimens to three or four different pathologists This by no means indicates lack of confidence in our pathologists, for we all know the difficulties of histologic diagnosis On the other hand, it is our duty to save the limb if the tumor is benign

Since the diagnosis is so extremely difficult in some cases, we do excision rather than amputation For after all, life cannot surely be saved in the malignant types of these tumors even by amputation The excision is followed by medullary nailing (figs 2087—2090) Thus the patients are at least made capable of walking, and if the diagnosis of sarcoma was wrong they have both life and limb

Treatment of Femoral Fractures from Lues and Tabes by Medullary Nailing These fractures usually are subtrochanteric fractures and sometimes occur bilaterally within a short period of time Callus formation is usually very slow or even wholly absent so that non-union develops Here, too, medullary nailing is advisable Chips from the bone bank should be added to stimulate callus formation In lues, antibiotics are given at the same time Later on, tabetic arthropathies at the hip, knee or other joints may develop (fig 2078)

Case History The patient shown in figure 2076 was admitted with severe varus, internal rotation and shortening of 4 cm After osteotomy the femur united in traction with good alignment and without shortening or rotation For two years he was able to do hard work, as he was not yet suffering from ataxy Then his gait became limping Just $2^{3}/_{4}$ years after the osteotomy, roentgenograms showed a pronounced arthropathy of the hip on the operated side (figures 2078) and in the talo-navicular joint on the other side When a surgeon told him it was wrong to operate on a tabetic person, he brought an action against me for $ 12,100 damages After a two year lawsuit I was acquitted Though arthropathy of the hip and talo-navicular joints had nothing to do with the osteotomy but were a consequence of the disease, and though the man was made fit for work for two years by that operation, I have since that time usually not done osteotomies in tabetic patients

Treatment of Femoral Fracture in Paget's Disease Medullary Nailing Formerly we treated all of these fractures with continuous traction and usually had good results (fig 2079, 2080) Since 1941 we have treated all these cases with closed or open medullary nailing The first four cases were published by Jorg Bohler [1] Hospitalization in three typical cases lasted an average of 27 days

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[1] Bohler, Jorg Results in Medullary Nailing of Ninety-five fresh Fractures of the Femur J Bone & Joint Surg *33 A* 670—678, 1951,

Behandlungsergebnisse bei 151 Marknagelungen des Oberschenkels Hefte zur Unfallheilkunde, Heft *46* 6—93, 1953

and the whole time of treatment was 151 days In spite of the relatively high patient ages of 58, 64, and 69 years, all joints regained full range of active movement If the bone is severely bent, as in figure 2078 h, an osteotomy is performed at the vertex of the curve The patients may get up ten days after the closed, or twenty days after the open, nailing

INADEQUATE "MODERN" TREATMENT OF A FEMORAL FRACTURE

Case History A 28 year old, strong and healthy man sustained a femoral fracture at the junction of the middle and distal thirds He was taken at once to the hospital, where he was treated in continuous traction of 15 Kg (33 pounds) through a Kirschner wire in the os calcis and with the knee joint extended To stimulate the formation of callus, he was given a daily dose of calcium and "Pro ossa" together with Vigantol every other day After four weeks the traction was reduced to 10 Kg (22 pounds) Since callus formation was thought to be "delayed", he was given an injection of his own blood every third day and treatment by deep X-rays every fourth day In the sixth week only 5 Kg traction remained, and the traction was removed entirely on the 42nd day The clinical history stated that the bone was firm but that there was still movement at the site of fracture(!) Roentgenograms showed a recurvation and a line of lesser density at the site of fracture, there being very little callus

On the 45th day, the notes run "Since removal of the traction, bone formation and the mobility of the knee joint have been stimulated by daily massage administered by a trained masseur The patient has begun to walk with crutches"

On the 54th day bending was noted at the site of fracture

On the 60th day "Marked bending has taken place Osteotomy cannot be undertaken, because callus formation is so slow"

Examination three months later showed shortening of 5 cm, marked varus position (25°), recurvation of 15° and an unstable knee joint The knee could be moved from 170 to 110° There was marked wasting of the muscles of the thigh An osteotomy was then advised, but the patient refused

In this patient all "advances" of so-called "modern science" were employed, e g·

1 Skeletal traction,
2 Chemical stimulants (calcium, "Pro ossa," "Vigantol"),
3 Biological expedient of "autotransfusion" or "autohemotherapy",
4 The radiologic method of deep X-ray therapy to stimulate the formation of callus,
5 The physiotherapeutic method of massage as given by a trained masseur, and finally,
6 Operation was proposed, but declined

What, then, was the result of this treatment, from which apparently nothing had been omitted in the attempt to achieve a good result? A young man with a short, crooked leg and a loose knee joint, who will be a cripple for the rest of his life

Is such treatment really scientific, even though such high-sounding terms as "biological," "radiological," etc, are used? I think rather that it is a sign of crass ignorance in this field

If, instead of applying 15 Kg (33 pounds) of traction through the os calcis with the knee extended, one had applied 10 Kg (22 pounds) through the tibial tubercle with the knee slightly bent, and then 9 Kg supracondylarly from the fourth week on, there would not have been any over-stretching of the

ents about the knee with the formation of a flail joint The use of too traction caused also distraction of the fragments and therefore delayed ormation of callus To overcome this, calcium, "Pro ossa," and "Vigantol" given, indeed from the very first day on, in addition to which came the ions of his own blood and the deep X-ray therapy All these methods unnecessary and, as the result shows, useless The essential and the most e condition for bony union was neglected, i e, immobilization of the reduced fracture fragments until they had united Firm lese bony union did occur so long as there was movement at the site of fracture No roentgeno-s were made for six weeks, from motives of economy Massage and passive ements after removal of the traction, before the bones were united, caused ive harm Effusion occurred in the knee joint and marked angulation e site of fracture These were increased by too-early weight bearing

f the surgeon had realized that a transverse fracture of the femur never mes firmly united in six weeks, he would never have thought it necessary se all the methods he did to promote callus formation Such a fracture ld have united firmly in good position with the methods previously ribed — that is, skeletal traction for eight to ten weeks instead of just six s, with a weight of 10 Kg instead of 15 Kg, with the pin for the first weeks in the tibial tubercle with the knee partially flexed and then later the pin in the femur, with systematic and adequate roentgen checks, and active motion rather than passive motion and massage There would have no shortening or angulation, no damage to the knee, and in four to months the patient would have been able to go back to work

ATMENT OF A FEMORAL FRACTURE BY FORCEFUL MEASURES

Case History On Feb 16th a 23 year old, strong and healthy man sustained a fracture ie right femur and was taken at once to the hospital The limb was found to be ened by 3 cm, rotated externally and severely swollen

Roentgenograms showed a transverse fracture at the junction of the middle and distal s of the right femur The distal fragment was displaced dorsally and medially by the width of the shaft, there was also a slight valgus and a 10° posterior angulation

Under general anesthesia, a Kirschner wire for traction was put through the tibial tubercle limb was placed on a lower leg splint and traction with 10 Kg arranged "according Bohler" (as stated in the case history) was applied On March 10, adhesive plaster ion was applied to thigh, lower leg and foot with weights of 5 Kg, 5 Kg and 1 Kg ectively

On March 16, first check roentgenograms were made The fragments were not yet fully ced, so pin traction through the tibial tubercle weighted with 14 Kg was re-applied for e weeks Then again adhesive plaster traction with little traction (weight not given) With bandage the femur became angulated into varus An operation was suggested On May fragments were reduced operatively, a Lane plate was applied and a plaster cast was on from the sole of the foot to but not including the pelvis A window was cut out over site of operation There was primary healing of the wound, and the cast was removed r six weeks Fracture was not yet sufficiently firm, so rest in bed had to be continued y massage and passive movements by an assistant therapist were started

On July 15, manipulation of the severely stiffened knee was attempted under general thesia This led to a transverse fracture of the patella without any considerable displace-t of the fragments Compression bandage and immobilization by a Cramer wire splint

Roentgenograms on July 21 showed loosening of the screws and angulation of the femoral shaft Fracture, of course, not yet consolidated, limb still unfit for weight-bearing Another operation was suggested

On July 22 a strong tibial graft was transplanted to the fracture site and fixed with wire loops, and a plaster cast from sole to pelvis for six weeks was applied The wound healed by primary intention After removal of the cast, massage and passive motion as well as baking were continued, at first with the patient in bed, then from September 20 on in the physical therapy department

Subsequently the fracture united with good callus formation Weight-bearing was started The knee, however, was considerably stiffened Patient started walking with the help of two crutches On October 22 he was discharged from the hospital and at that time could walk with two sticks As an out-patient he was treated with radiant heat, massage, and with a passive-motion apparatus

Patient was again in the hospital from December 22 to January 4 for mobilization of the right knee, which had not been much influenced through physical therapy There was considerable stiffness of the knee (extension contracture) So the knee was flexed over a wooden wedge with the patient under general anesthesia Suddenly there was an audible snap in the right lower leg and angulation occurred at the site from which the graft had been removed in July Walking plaster was applied at once, but roentgenograms showed an angulation fracture of the tibia and he was kept for a few days in bed

On January 4 he was discharged with walking plaster The result of manipulation was poor

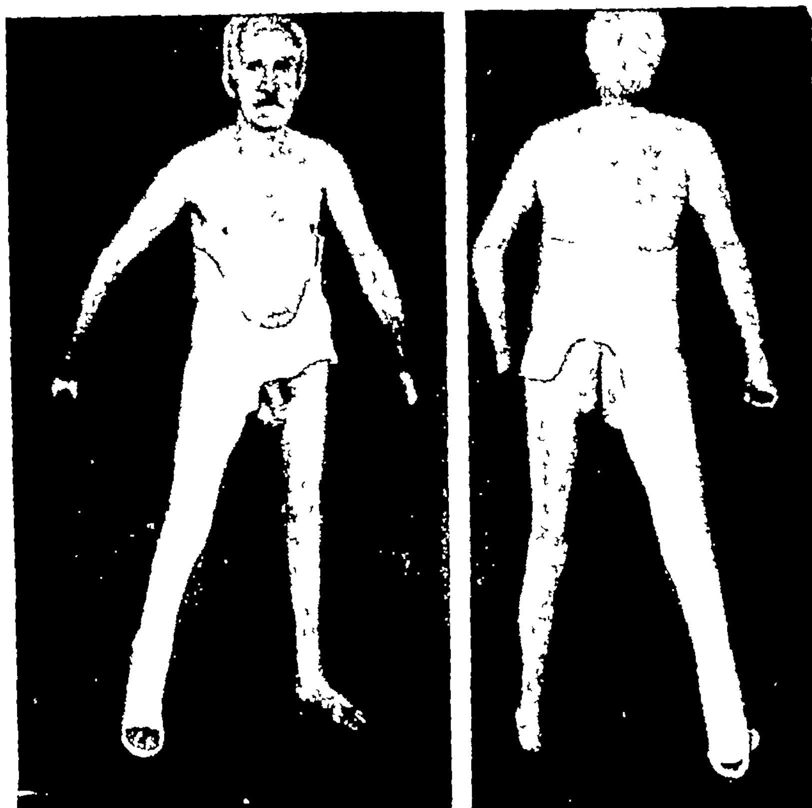
A new plaster cast was applied on January 20 and the knee was treated with radiant heat, massage and motion When on February 10 the lower leg plaster was removed, the fracture was firm

On March 30 the patient could walk with one stick, and knee motion was 180° to 160°

The treatment of such a femoral fracture is rather simple in a healthy, strong young man If a pin or wire is put through the tibial tuberosity under local anesthesia, if the limb is placed on a Braun splint and if the traction is weighted with one-seventh of the body weight, shortening and angulation usually disappear Then if roentgenograms are made every two or three weeks the position of the fragments can be checked and, if necessary, corrected Within eight to ten weeks such a fracture usually unites in good position and weight-bearing may be allowed The patient will use quadripod canes for the first few days, after one week he will need the help of one or two sticks only *Without* any follow-up treatment at all the knee joint of a 23 year old man regains full active motion after two to four months. In about 1000 closed femoral fractures treated by us, the range of knee motion was in most cases more than 90°

In this case the roentgenograms after four weeks showed correction of the shortening but a dorsal displacement of the distal fragment by the full width of the shaft and a recurvation of 10° After two to three days, further check roentgenograms should have been made The dentated fracture ends could have been apposed if a slight lengthening has been effected by temporary traction of 12 Kg and then return to 10 Kg The usefulness of the limb after a fracture of the femoral shaft, however, is normal even if the fragments remain displaced by the full width of the shaft, provided shortening, angulation and rotation have been corrected (Vol I/figs 261—286) Recurvation could have been corrected easily by putting a pad under the fracture site or by pulling the knee joint distal to the knee-angle of the Braun splint as shown in figures 2007—2008 Instead of this, traction was weighted with 14 Kg from

the fifth to the eighth week The result of this traction was not checked by roentgenograms Such excessive traction usually damages the knee joint and makes it loose, and it also delays callus formation After seven weeks an adhesive tape traction was applied with too little weight The result was a marked angulation of the femur with a varus of 30° Such angulation can easily be noted even without roentgenograms When roentgenograms were made after eleven weeks they showed the severe angulation of 30° and good callus formation Such angulation can easily be corrected under a short anesthetic (compare Vol I/figs 271—280) and the achieved good position



2081 2082

FIGS 2081, 2082—Well-moulded walking plaster spica seen from in front and behind The moulding between the trochanter and the crest of the ilium is particularly important, as this will prevent cranial displacement of the femur Buttock correctly covered The buttock on the injured side should not be too widely exposed because the edge of the plaster would then cut into the skin (cf figure 1578) In fractures through the distal third, the cast is cut away to the iliac crests so that the patient can sit better

easily maintained by traction of 10 Kg or a plaster cast The bone would have become firm and capable of weight-bearing within another three to four weeks, and the knee joint could have been moved again a few weeks later Instead of this the fracture was operated on, the good callus was removed, and a Lane plate was inserted Then a plaster cast extending to but not including the pelvis was applied for six weeks Although the fracture was not yet firm after this time, no new plaster cast was applied Rather, daily massage and

passive motion were started and, of course, failed Such operations near the knee joint with an approach through the vastus lateralis usually cause a long-lasting limitation of knee motion To overcome this, the knee was flexed under a general anesthetic with such force that the patella broke and the fracture of the femur became loose in spite of the plate and screws The screws were too short and did not perforate both cortices. Reangulation of 20° occurred If, at that time, the fracture fragments had been properly aligned with the patient under a short anesthesia and then the fragments immobilized in an adequate plaster cast, the patient could have started walking one or two days later and the fracture would have united within a few weeks Instead of this, a new major operation was performed A long, strong, tibial graft was transplanted to the fracture site and another plaster cast without inclusion of the pelvis was applied for six weeks Massage and passive motion followed At that time the fracture was said to be firm and capable of bearing weight, the knee, however, was stiff Roentgenograms of Dec 19 show that the fracture had not been firm at that time, since in that case no reangulation of 15° could have occurred Another cause of reangulation was that the lower end of the graft was not fixed by a loop As joint motion failed to improve "in spite" of physical therapy, five months after the second operation the knee was flexed again under a general anesthesia with such force that the tibia broke through the donor area of the graft

A stiff knee can never be made mobile by forceful manipulation but *can* be damaged considerably In such cases of extension contracture, the mobility of the knee can only be restored by an open operation after Payr (figs 2215 through 2224 and page 1473)

The result of this rather drastic treatment through a period of 13 months was a deformed thigh and a stiff knee in a 24 year old healthy man

In the treatment of fractures it is essential *to reduce* the fragments, then *to immobilize* the fragments *uninterruptedly* until they have united, and to let the patient actively *exercise* as many joints as possible during the time necessary for immobilization In femoral fractures the position of the fragments can best be retained by continuous traction, but one should avoid switching back and forth between too much and too little traction weight One should strive to have just the correct weight pulling in just the right direction all the time Traction should not be removed before the fracture has consolidated Also after operation with a Lane plate or a bone graft, a firm cast must be applied including both neighboring joints, i e the hip as well as the knee, until the callus has become firm and capable of weight-bearing This may be six weeks or longer, the latter being true in this last case In such a case the immobilizing cast should have been retained longer, as neither a Lane plate nor a bone graft alone is capable of holding the fragments sufficiently firmly One should also keep in mind that stiffened joints are nothing on which to try out one's strength One can make such joints mobile again only by use of slight forces acting through a long time

If the surgeon had known these fundamental rules of the treatment of fractures, he would not have thought it necessary to perform four major

surgical interventions and thereby cause harm to the patient The patient's present condition is not the consequence of the accident, but rather the result of an ill-planned and excessively active and energetic treatment

OPERATIVE TREATMENT OF RECENT CLOSED FRACTURES OF THE FEMUR BY UNSTABLE OSTEOSYNTHESIS

The justification given for operating upon fractures of the femur is that conservative methods often fail to correct shortening and to remove the interposition of soft parts This argument must be met with a direct negative, because by means of skeletal traction any shortening *can* be corrected and interposition of muscle usually corrected at the same time. Lateral displacement is the most common excuse for operative treatment We have, however, pointed out in Vol I/pp 218 and 219 that lateral displacement by even the full width of the shaft is of no cosmetic or functional concern in fractures of the femoral shaft provided there is neither angulation, rotation nor perceptible shortening (Vol I/figs 261—280, 2016—2022, 2132—2137)

Up to 1941 I warned against operative treatment expecially because of the danger from infection and because the old methods with short plates and short screws, with clamps and wires (Vol I/figs 258—260), and with short ivory, bone or metal bolts, applied without an additional plaster cast or traction bandage, did not ensure sufficient stability This is shown in figures 2091—2098

The great danger of infection before the introduction of antibiotics has been described in detail in Vol I/pp 220—229 Figures 2165 and 2166 l—n show that we were able to achieve good results without osteosynthesis in more than 600 fractures of the femoral shaft

The possible untoward results of operation in closed fracture of the femoral shaft were stressed in a report published by Beck, of Kiel, Germany, in the journal *Chirurg*, 1932, vol 2

A 17 year old farmer had had an uncomplicated (closed) transverse fracture of the proximal third of the femur following a fall from a horse two and a half years before An operation was done eight days after the accident because it was supposed that the displacement was impossible of reduction The fragments were fastened by means of an intramedullary peg taken from the fibula of the same side The wound suppurated, and the piece of fibula was removed from the femur, skeletal traction was applied above the knee with Schmerz's clamp, and early active and passive movements in the knee and foot were begun In spite of this, the knee was markedly stiffened a year later, allegedly because the patient had lost energy The fracture was firm, but a chronically-draining sinus remained The patient was treated for a long time at home, trying to walk with the help of two canes But as his condition did not improve he was finally sent back to the hospital

The condition on admission was as follows The right thigh showed slight varus angulation in the middle On the outer side of the thigh there was a long operation scar and in the middle of the scar an open sinus The femur was much thickened above the middle, the fracture being firmly united The knee joint was in extension and permitted active and passive movements of only 15° to 20° Further attempts at movement were painful On the outer side of the lower leg was a long operation scar, and the foot was in a position of talipes equino-varus, Active dorsiflexion was impossible, as there was complete peroneal paralysis The hip showed limitation of abduction and flexion in comparison with the other side, the other movements being free

Roentgenograms showed there was a large sequestrum at the site of fracture, but the fracture itself was bridged by a strong piece of bone on the inner side The knee joint showed marked atrophy of the bone, diminution of the joint space, and an irregular proliferation of the bone as evidence of severe arthrosis deformans The leg was shortened $1^1/_2$ to 2 cm, walking was difficult even with the help of two canes

It may be fairly said that the operative treatment of this fracture had led to everything which it is desirable to avoid a long and severe illness, a shortening of the leg amounting to 2 cm, a serious limitation of movement in the knee with severe deforming arthrosis, a permanent peroneal paralysis and a permanent interference with the man's earning capacity The young man is now 17 years old, with his earning capacity reduced 40 to 50 per cent This will have to be borne by the insurance company One hundred per cent of these disabilities might certainly have been avoided if operation had not been performed

In contrast to these bad results I have seen good results from operations, particularly in patients treated by Sherman and Albee But good results may also be obtained without operation and therefore without the dangers accompanying operation

67. MEDULLARY NAILING (KÜNTSCHER)

As described in detail in Vol I/pp 214—217 and 233, the dangers of operative treatment of fractures are: (1) Operative shock, (2) Infection, (3) Delayed callus formation or non-union, (4) Damage from foreign bodies, and (5) Disturbance arising from defective technique

1 *Damage From Operative Shock.* **Medullary nailing must not be carried out in a patient in severe shock, as is usually the case in multiple injuries, because it may lead to a fatal outcome.** The operation is never urgent and should therefore be postponed until the shock has been treated successfully The application of pin or wire traction is usually the simplest means of temporary treatment in such a case When the patient has recovered from shock, medullary nailing can be performed if no further contraindication exists

2 *Avoidance of Infection* Next after shock, problems resulting from infection used to be the most serious complications in operative treatment. They have caused untold numbers of deaths and amputations and have caused often severe damage to limbs which have survived (see Vol I/pp 215 and 220—229, figs 258—260 and 1036—1038, Vol II/figs 2091—2093 and 2505—2508, M N/figs 490—526, 864—873, 894—901 and 1136—1145)

In 1940, Küntscher[1] *published his new method of closed medullary nailing for osteosynthesis of the femur Through a small incision distant from the fracture field, a long, strong and suitably-shaped steel rod — the "medullary nail" — is inserted With correct technique this nail unites the fragments so firmly that the broken limb, as in a nailed fracture of the neck, can usually be lifted immediately and that weight-bearing can be started without external support within one to three weeks All joints can immediately be actively exercised After bony union has been achieved, the medullary nail can easily be removed by a minor operation*

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[1] Küntscher, G Die Technik der Marknagelung des Oberschenkels Zentralbl f Chir 25 1940

Of chief importance is the fact that the introduction of the medullary nail through a small incision distant from the fracture site without direct exposure of the fracture ends minimized the danger of infection with which earlier operative methods had been so heavily encumbered This has been demonstrated already in thousands of cases

From 1941 to 1948 we carried out closed medullary nailing in 58 out of 61 cases of closed fractures of the femur Jorg Bohler (see page 1454, foot-note) found amongst these patients only one case of infection, that being a case in which the nail was mistakenly driven in through a burn, i e, an infected area As we have had sufficient penicillin and other antibiotics since 1948, we nowadays employ the open method of medullary nailing instead of the closed method even in closed fractures

3 *The danger of delayed callus formation and non-union* is small if the cases are carefully selected and if the correct technique is used Osteosynthesis is so firm that additional external support such as afforded by plaster cast or traction is unnecessary This is contrary to the post-operative situation of former times when wires, plates with screws, and short bolts were used The fragments can slide along the nail and so can by muscle-pull and by weight-bearing forces be pressed tightly against one another All injurious traction, shearing, and laterally displacing forces are excluded or combatted by the medullary nail, and usually only advantageous compression forces are encouraged or permitted by it Callus formation is therefore furthered, as in the nailed fracture of the femoral neck, whereas it is often hindered by Lane plates since the screws of the plate prevent the fragments from approaching each other Moreover, in closed medullary nailing the multiple tiny bone splinters so helpful to healing remain and the periosteum and surrounding tissue suffer no further damage Kuntscher's assumption that callus formation is stimulated by the medullary nail has unfortunately not been found to be correct

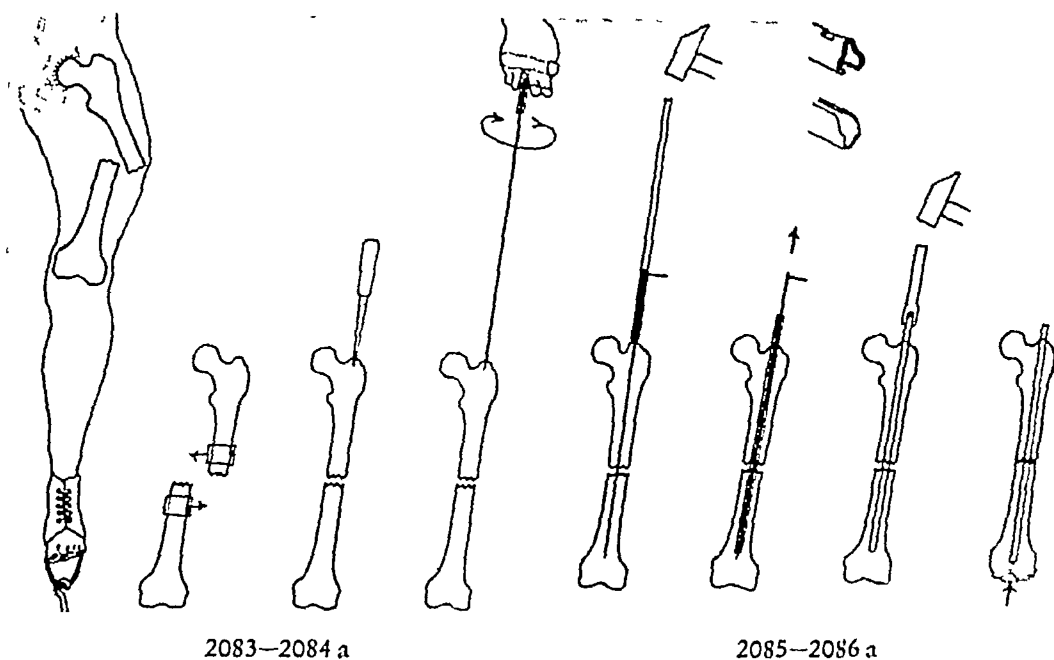
4 Damage from the effect of chemical or electrolytic foreign materials no longer occurs, as amagnetic, stainless steel is used Formerly, severe corrosion sometimes occurred with the use of martensitic, magnetic steel, as shown in M N /figs 264—276

5 *Troubles resulting from defective technique* are common if the operation is undertaken without proper preparation or without the essential instruments and apparatus by an inexperienced surgeon It is essential to use two X-ray tubes instead of one in closed medullary nailing It is important to measure width and length of the medullary space before the operation The medullary nail should be neither too thick nor too thin, neither too short nor too long The nail must be inserted at just the right place, etc Possible complications are described in M N /pp 74—89 and 144—163 M N /figs 590—595, 697—704 and 161—170 show some results of defective technique Some extra-ordinary cases were reported in the Journal of Bone and Joint Surgery, 1951-B, p 1 The greatest damage results either from the omission of accurate measurement of the length and width of the medullary canal or from failure to make a sufficient number of roentgenograms

With knowledge of and proper regard for the contraindications mentioned in M N/pp 8—11, i e, with proper selection of the cases, and with correct operative technique, medullary nailing (Küntscher) is vastly superior to all previously known methods for the treatment of fractures of the femoral shaft.

Theoretically, medullary nailing should be considered for use in the following conditions

1 In fresh closed fractures,
2. In fresh open fractures,



2083—2084 a 2085—2086 a

Closed Medullary Nailing

Fig 2083 —Transverse fracture in the middle third of the femur with varus, lateral displacement and shortening under longitudinal traction

Fig 2083 a —After correction of the angulation and shortening the lateral displacement is corrected by lateral traction

Fig 2084 —After exact reduction the greater trochanter is pierced with an awl

Fig 2084 a —The guide pin is inserted through the awl hole be means of a handle

Fig 2085 —If the roentgenograms show good position of the guide pin, the medullary nail is driven in over it

Fig 2085 a —When the head of the nail approaches the skin, the guide pin is pulled out

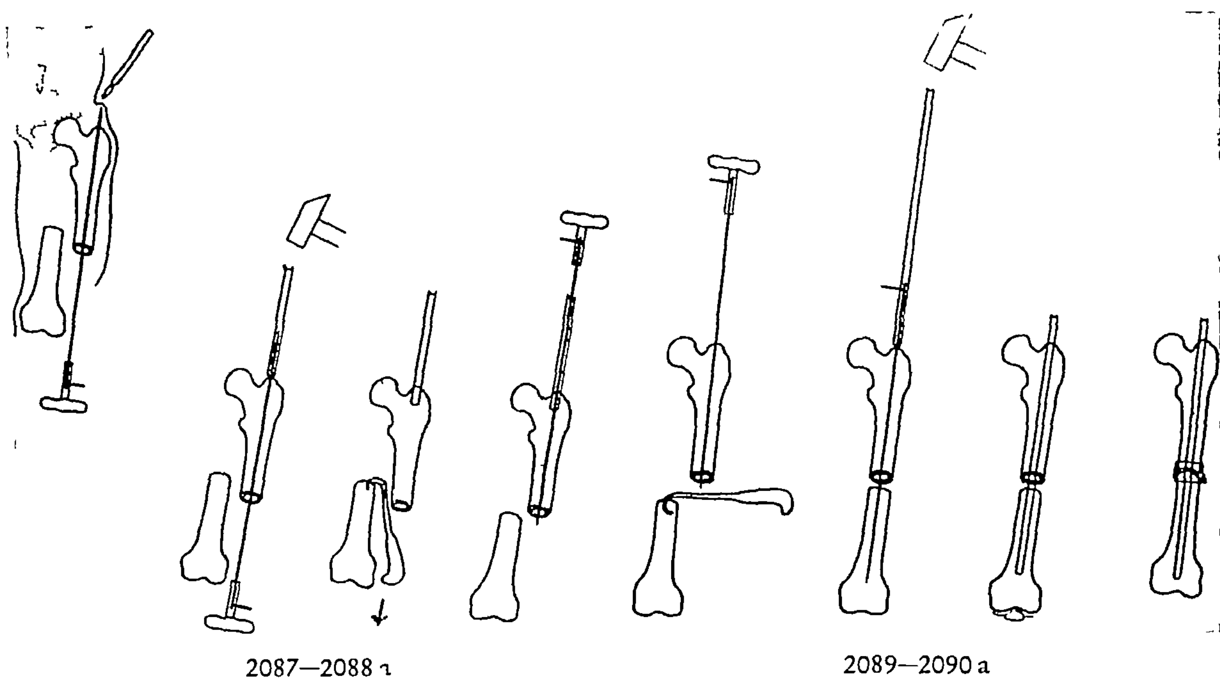
Fig 2086 —For the further driving of the medullary nail, the punch with the 2 cm bore is used

Fig 2086 a —After the nail has been driven in far enough, i e until it protrudes only 2 cm beyond the trochanter, the fragments are impacted by blows with the hand against the flexed knee

3 In fresh gunshot fractures,
4 In infected and draining fractures,
5 In old fractures,
6. In malunited fractures,
7 In non-union,

8 For shortening of the sound femur,
9 For shortening of the bone in nerve-defects due to gunshot wounds,
10 For shortening of the bone in vessel-defects due to gunshot wounds, and
11 In benign bone cysts

We have used medullary nailing in all these conditions with the exception of infected fractures with chronic sinuses It should not be used in such cases, and we have seen severe late complications (recurrent chronic osteomyelitis) in patients operated elsewhere Even antibiotics offer no reliable protection in these cases



Open Medullary Nailing

Fig 2087 —In open medullary nailing the guide pin is inserted into the proximal fragment from below and pushed through the greater trochanter Where it bulges the skin a 2 to 3 cm incision is made

Fig 2087 a —A short medullary nail is slipped over the guide pin and pushed down to the greater trochanter

Fig 2088 —The short nail is driven 1 to 2 cm into the greater trochanter The guide pin is pulled out from below Shortening is corrected with a single-pronged hook

Fig 2088 a —Another guide pin is inserted from above through the short medullary nail

Fig 2089 —Lateral displacement is corrected with the single-pronged hook

Fig 2089 a —After exact reduction, the guide pin is pushed towards the knee joint The medullary nail of proper length and thickness is driven in with a hammer

Fig 2090 —The nail has been driven to near the knee joint The fragments are impacted by blows on the flexed knee

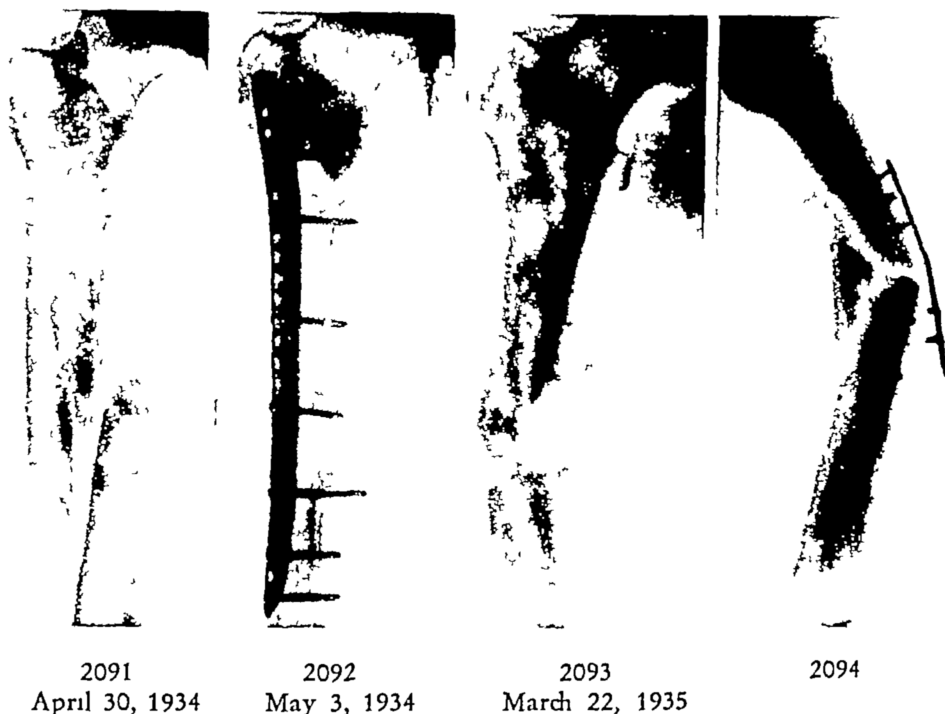
Fig 2090 a —After impaction of the fragments they are secured against rotation by a wire loop

Closed Medullary Nailing

It should be performed only if the instruments listed in M N /pp 22—26 are at hand Besides, blood donors or a blood bank must be available The medullary nails must be checked with a magnet before the operation

The operative technique is shown in figures 2083—2086 a and described in M N /pp 37—50 and 164—186

Closed medullary nailing is rejected by many surgeons because of the danger that they may suffer radiation damage if they do such operations often and also because of the danger of radiation damage to the patient if the operation lasts a long time and many exposures are made Furthermore, closed medullary nailing is difficult to perform if suitable reduction apparatus and two X-ray tubes are not available That closed nailing is possible is adequately demonstrated by the fact that from 1941 until 1948 we succeeded in doing it in 58 out of 61 cases of fresh, closed fractures of the femur Under the protection of antibiotics, we now prefer the open method of medullary nailing even in many closed fractures



2091 April 30, 1934 | 2092 May 3, 1934 | 2093 March 22, 1935 | 2094

FIG 2901 —Long torsion fracture of the femur with a big medial torsion wedge, sustained by a 22 year old man who fell when skiing

FIG 2092 —Check roentgenograms re figure 2091, three weeks later One of the most competent exponents of osteosynthesis reduced these fragments and fixed them with a metal plate 25 cm long

FIG 2093 —Check roentgenograms re figures 2091 and 2092, eleven months later A severe infection developed after operation After six months the metal was removed, the wound healed after nine months As the fragments were not yet united when the plate was removed six months after the operation, a varus of 20⁰ developed There was severe swelling of the limb eleven months after the operation Knee motion 170⁰—140⁰, motion of other joints limited by half

FIG 2094 —Flexion fracture of the femur ten weeks after the injury Four days after the accident this patient was operated on by a well-known authority on osteosynthesis Plaster cast for five weeks Then the patient could not walk because the limb was painful and swollen Angulation developed As the plate was too weak, it had bent, the screws, being too short, had broken With the use of such a small plate and such short screws the plaster cast should have been left in place for 8 to 10 weeks

Open Medullary Nailing

This is much easier than the closed method, since the fragments can be apposed in the open wound The danger of operative shock is greater than in the closed method, since considerable loss of blood may occur Therefore blood should be given during the operation The danger of infection can be combatted by the use of antibiotics The danger of delayed callus formation and non-union can be combatted by the application of bone chips from the bone bank In every open medullary nailing, especially in cases of transverse fracture, we insert a longitudinal wire loop to secure the fragments against rotation The drill holes for the wire should be not more than 1 cm distant



2095 2096 2097 2098

Fig 2095 — Attempt at osteosynthesis with a metal clamp and then a plaster cast for four weeks in a 25 year old man Healed with a varus of 40° Knee motion severely limited

Fig 2096 — Attempt at osteosynthesis with two short Y-shaped metal plates and three short screws in a 19 year old youth As not enough screws were at hand, the metal plates were fixed with wire to the proximal fragments Then a short splint was applied and left for a few weeks Varus of 65° Big callus bridge at the medial side of fracture, but no callus bridging the fracture itself Knee stiff

Fig 2097 — Transverse fracture in the middle third of the femur in a 23 year old man, operated on and fixed with two metal plates and short screws Plaster cast removed after five weeks Then bending of the femur and breaking of the short screws Antecurvature 30° Knee motion 160°—130°

Fig 2098 — Operated femoral fracture from which the plate was removed after three months because it was bent and broken Three far-too-short screws still buried in the callus Varus of 15° Knee motion 170°—135°

from the fracture ends Unfortunately, damage from improper technique is not uncommon

The technique of open medullary nailing is shown in figures 2087—2090 a and described in M N /pp 186—196



2099 2100
September 16, 1947

2101 2102
September 16, 1947

FIGS 2099, 2100—*Open* fracture at the junction of the middle and distal thirds of right femur The wound was accurately excised at once and a medullary nail driven in The smaller fragments were fixed with three wire loops Then the wound was closed Healing of the wound was uneventful

FIGS 2101, 2102—Closed transverse fracture of left femur treated with pin traction Closed medullary nailing was performed 16 days after the accident

2103, July 9, 1948

2104, July 20, 1948

FIG 2103—Check roentgenogram re figures 2099–2102 10 months later Bony union of both femora

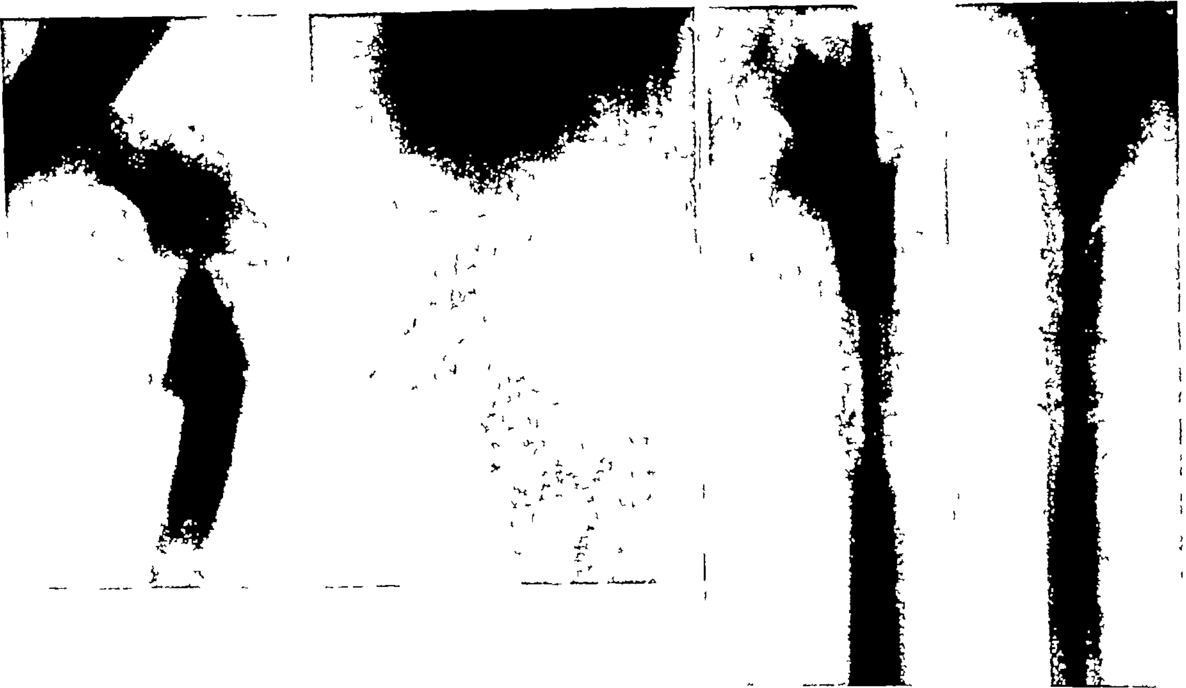
FIG 2104—Check roentgenogram re figures 2099-2103 Condition after removal of both medullary nails Both fractures have firmly united

FIGS 2099-2117 and 2145–2153 are from the paper by Bohler, L, and Böhler, J "Küntscher's Medullary Nailing," J Bone & Joint Surg *31-A* 295–305, 1949



February 12, 1948

FIGS 2105, 2106—Photographs re figures 2099—2104, five months after the accident The patient started walking four weeks after the accident Six weeks after the accident both knee joints could be flexed through 90°



2107 July 7, 1948 2108 2109 August 9, 1948 2110

FIGS 2107, 2108—*Open* comminuted fracture of the left femur sustained by a 44 year old traffic policeman who was run over by a car He had wounds on the ventral and dorsal sides of the thigh The distal fragment is displaced dorsally by three times the width of the shaft The wounds were excised accurately The main fragments were fixed with a medullary nail and the smaller fragments were fixed to the nail with four wire loops Uneventful healing of the wounds

FIGS 2109, 2110—Check roentgenograms re figures 2107 and 2108, four weeks later All fragments have been well reduced Patient got up eight weeks after the medullary nailing

In torsion fractures with a torsion wedge, the broken-off wedge fragment is fixed with 1 or 2 wire loops to the proximal fragment before the guide pin is inserted If multiple fragments of varied sizes are present, as in fig 2107 and in M N/figs 618—633, the largest of them is first fixed to the proximal or to the distal fragment and then the nail inserted If only small splinters are present, the medullary nail should be introduced first and the splinters then fixed to the nail with wire loops Big fragments may be screwed onto one of the major fragments

What Should Be Done if a Medullary Nail Has Been Inserted Part Way and Then Can Be Neither Driven Farther in Nor Removed?

In addition to what has been written in M N/pp 56 and 57 about this severe complication, we should like to say that the nail can usually be driven in or out easily if the bone is incised longitudinally at its isthmus with an electric circular saw If necessary a thin medullary nail can then be inserted and the incised bone closed with two wire loops

68. FRESH OPEN FEMORAL FRACTURES

In fresh open fractures of the femur which are admitted for treatment within the first six to eight hours, the wounds are accurately excised under local anesthesia according to the rules given in Vol I on pages 142—173 It is usually necessary to enlarge the wound by longitudinal incisions proximally and distally so as to be able to see clearly all the soiled and torn tissue All devitalized tissue must be excised, but not 1 mm more Vessels and nerves should insofar as possible be carefully preserved In the patient shown in *Vol I/figs 234—240, 600 g of lacerated and dirty muscle was removed* He regained complete usefulness of his limb

The circumstances mentioned in *Vol I/p 173* should be carefully considered in order to avoid failures In addition, one gives penicillin and, if indicated, also other antibiotics until the temperature has remained normal for three days.

Treatment With the Medullary Nail Since 1941 we have usually inserted a medullary nail after accurate excision of the wound in those patients not in severe shock The operative technique of medullary nailing in open femoral fractures is shown in figs *2087—2090 and described in M N/pp 187—196* The achieved results are demonstrated in figures 2099—2110 and discussed in M N/figs 608—648 In the patient shown in M N/figs 618—638, we would now fix the bone splinters with stainless wire loops as in figures 2107 through 2110 Then no supplementary traction is necessary In the presence of a small bone bridge, in which there tends to develop a fatigue fracture as shown in M N/figs 630 and 631, we now add an autogenous or a bone bank graft

End-Results Among 26 fresh, open femoral fractures which we have treated by medullary nailing we have seen only one slight infection, and that one led to no permanent disturbance [1]

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[1] Bohler, Jorg Results in Medullary Nailing of Ninety-five Fresh Fractures of the Femur, Bone Joint Surg *33 A* 610—618, 1951

Fixation With the Angulated Blade-plate In supracondylar fractures where the distal fragment is shorter than 8 cm we sometimes use a long, angulated blade-plate as shown in figure 2006 and described on page 1408

Treatment by Continuous Traction If shock should develop or persist despite treatment with local anesthesia, heat and blood transfusion, the wound is closed by suture of the skin *alone* after insertion of a drain No vessel ligatures or deep sutures are buried Then the fracture is treated by continuous traction as described on pages 1383—1391 Care must be taken to avoid excessive traction and the consequent distraction of the fragments and non-union (figs 2111 and 2150—2156) One-tenth and not one-seventh of the body weight should be used for such traction in open fractures

Treatment with the Plaster Hip Spica The plaster cast is sometimes used in supracondylar femoral fractures if the distal fragment is shorter than 8 cm and cannot be caught with the medullary nail

Amputation of the Thigh If the femoral artery is ruptured in a case of femoral fracture, amputation should usually be carried out immediately to avoid gangrene and gas-gangrene Suture of the artery or implantation of a vessel graft should be considered only if medullary nailing is possible

69. INFECTED FEMORAL FRACTURES

If an open fracture of the femur is admitted for treatment later than eight hours after the injury, the torn and soiled and bloodless tissues are excised If, as a sign of infection, the wound shows the presence of pus, it must be kept open and *must not be sutured*, in order that one avoid increased tissue tension, cellulitis and gas-gangrene

In case of phlegmonous cellulitis, all pus foci must be freely exposed as described and shown in Vol I/pp 193—195 and figs 242—246 Penicillin and, if necessary, also other antibiotics are given

In case of mild inflammation the fracture is treated by *continuous traction* (see pages 1383—1391) The traction weight must never exceed 6 Kg, and it must sometimes even be reduced to 3 Kg to avoid distraction with all the poor sequelae described in Vol I/pp 25—27

In severe inflammation, after exposure of the pus foci a *thoracopelvic plaster hip spica is applied (see page 1393)* Sometimes it will be expedient to include the sound leg in the plaster cast, too

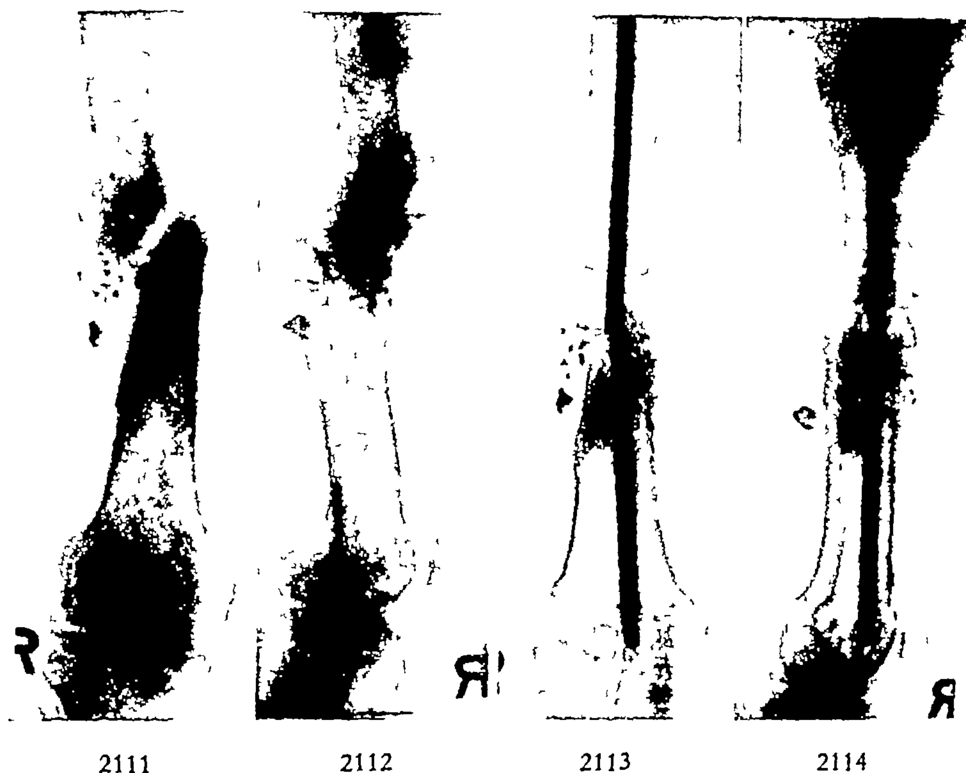
The circumstances mentioned on page 197 of volume I should be taken into consideration to avoid failures

70. OLD AND MALUNITED FEMORAL FRACTURES

Adults will usually limp and have complaints later on if angulation of more than 15°, even slight rotation, or shortening of more than 3 cm have resulted from a femoral fracture Therefore, these should be corrected if the patient's general condition and other circumstances permit it In children such displacements will disappear by themselves if they are not too severe, as has been pointed out on page 1435

Troubles because of angulation sometimes develop as late as 20 years after injury This is shown in the following case, which I published in 1942.[1]

An 18 year old boy broke his right femur proximal to the middle of the shaft. He was operated on and the fragments fixed with a Lane plate Union occurred with a varus of 15° The following year he became a football champion and remained so for years When he was 38 years old, i e. 20 years after the accident, he felt pain in the medial side of his right knee joint Roentgenograms showed the medial part of the joint space, where the pressure was increased through the varus, to be narrowed and bordered by marginal exostoses All other joints were normal



2111 2112 2113 2114

January 10, 1946 June 1, 1947

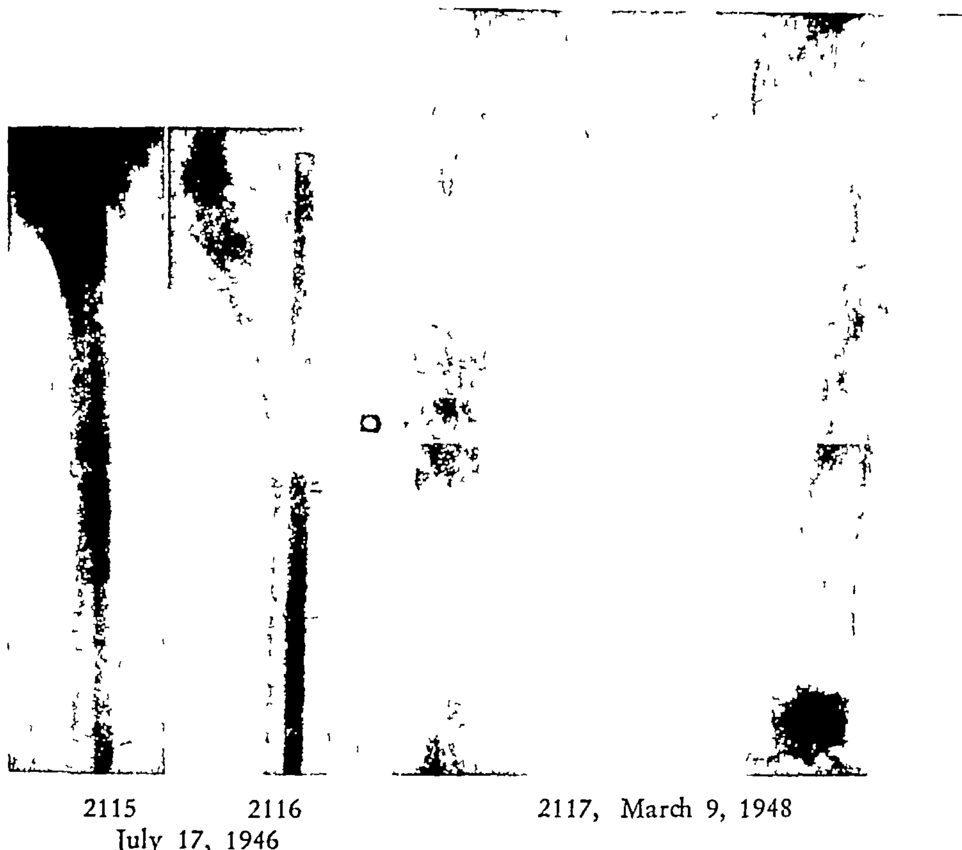
FIGS 2111, 2112—Non-union of right femur in a 23 years old student who had sustained a gunshot fracture three years previously He was treated, and distracted, *elsewhere* by wire traction weighted with 12 Kg Non-union developed with shortening of 9 cm The fracture ends are sclerosed Multiple shell splinters lie in the soft tissues

FIGS 2113, 2114—Check roentgenograms re figures 2111 and 2112, seventeen months after open medullary nailing The medullary nail has broken The fracture is not yet firm Continuous traction led to accurate apposition of the fragments of the nail Through a small incision over the trochanter the fragments of the nail were removed with the technique described in M N/p 85 Then a new medullary nail was driven in

Correction of Displacement

Within the first 4 to 6 weeks, marked shortening and angulation can usually be corrected in continuous traction Further treatment is then carried out as in a fresh femoral fracture by further continuous traction (see

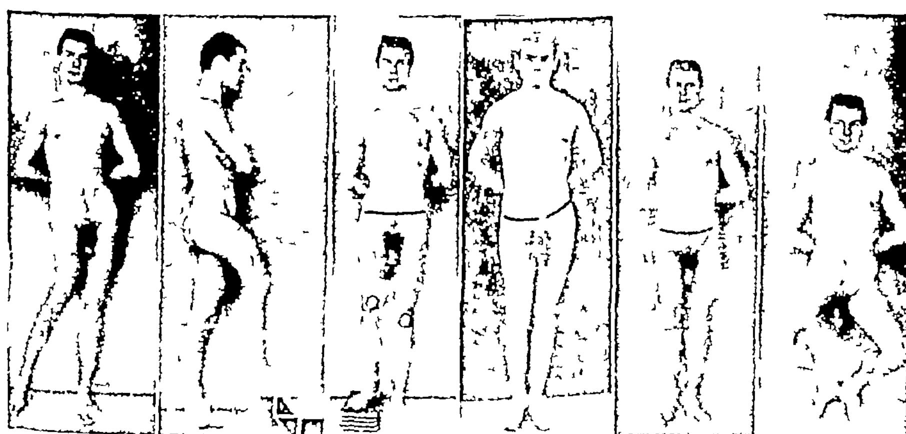
[1] Bohler L Der Einfluß von Achsenknickungen auf die Gelenke des Beines, Der Chirurg, 6 1942



2115 2116 2117, March 9, 1948
July 17, 1946

FIGS 2115, 2116 —The left femur was shortened by 8 cm and a medullary nail was inserted A wire loop was applied as insurance against rotation

FIG 2117 —Check roentgenogram re figures 2111—2116, after removal of both medullary nails 20 months after operation on the right femur and 16 months after operation on the left Both femora have united in good position The intention was that the right limb was to be 1 cm shorter than the left



2118 2119 2120 2121 2122 2123
January 19, 1946 June 6, 1946 March 9, 1948

FIGS 2118, 2119 —Photographs re figures 2111, 2112 Abnormal mobility and 9 cm shortening of right thigh Knee motion 160°—170°

FIGS 2120, 2121 —After medullary nailing the right limb is straight but still 9 cm the shorter

FIGS 2122, 2123 —After shortening of the left femur the patient has become 8 cm shorter Lengths of lower limbs about equal After quadricepsplasty the right knee can be flexed to 90°

pages 1383—1391 and figures 1604—1608), by a thoracopelvic plaster hip spica (see pages 1393—1396) or by medullary nailing (see page 1448).

After 6 to 12 weeks the fracture has usually acquired some firmness The young callus must be broken over a wooden wedge or with Phelps-Gocht's (fig 138) or Schultze's osteoclast if further treatment is to be carried out in continuous traction (Vol I/figs 261—280, figures 2125—2128 and 2131 through 2144) Shortening and angulation can be eliminated with traction, but lateral displacement cannot Vol I/figs 261—280, and figures 2131—2144 show that this seldom affects shape, power and/or motion of the limb in later years This fact should be stressed, since most open operations and



2125 April 10, 1926 — 2126 June 20, 1926 — 2127 April 10, 1926 — 2128 June 24, 1926

FIG 2125—Subtrochanteric torsion fracture of femur with big lateral torsion wedge, 10 weeks after the injury Fracture united with 30° varus and 6 cm shortening Little callus formation

FIG 2126—Check roentgenogram re figures 2125, ten weeks later The femur was refractured over a wedge and then treated by continuous traction for eight weeks (three weeks with tibial pin traction, five weeks with Unna's paste traction) Healed without shortening and without angulation

FIG 2127—Photograph re figure 2125 Shortening of 6 cm, and varus

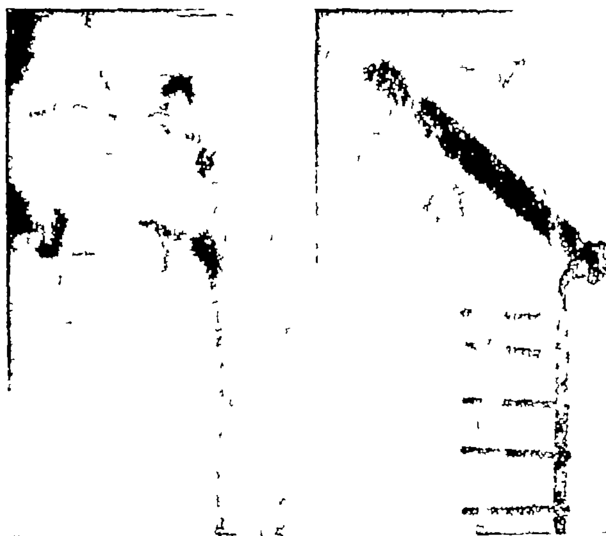
FIG 2128—Photograph re figures 2126 and 2127, ten weeks later Shortening and angulation have been eliminated

bone sutures have been carried out not to correct angulation but to correct lateral displacement.

Osteotomy In United Femoral Fractures If the fragments are firmly bridged by bony union, which is sometimes the case as early 4—6 months after injury, the fragments should be exposed by a lateral incision If continuous traction is planned as further treatment, the bone should be chiseled through as obliquely as possible so that the osteotomy ends can be apposed over wide

surfaces In the case shown in figures 2145 and 2146, the old callus was excised after osteotomy of the fracture site and the new surfaces were largely freshened Then the wound was closed after insertion of a drain, and pin traction was applied as in fresh fractures of the femoral shaft (see pages 1383 through 1391)

Determination of the Traction Weight Within the first week, traction is exerted with a seventh of the body weight just as in a fresh femoral fracture This usually eliminates the angulation, whereas lateral displacement and some shortening remain. This latter favors callus formation, and the nerves and vessels are of course not over-stretched In accord with the findings on the check roentgenograms, in the course of the second week the traction weight



2129, April 15, 1954 2130, May 25, 1954

FIG 2129—Eight month old subtrochanteric fracture of the left femur sustained by a 57 year old farmer who fell from a height of 3 meters Coxa vara of 90°, severe external rotation and shortening of 5 cm

FIG 2130—Check roentgenogram re figure 2129, six weeks later After insertion of a three-flanged nail, a bone wedge with a base of 22 mm was excised from the lateral side of the femur The coxa vara was corrected by apposition of the osteotomy surfaces, the external rotation was corrected by internal rotation of the distal fragment The distal fragment was fixed to the proximal one with a plate and five screws Patient got up without supplementary external support three weeks after operation

is increased until the shortening has been overcome If 2 Kg more than one-seventh of the body weight are needed for longitudinal traction, a new pin is inserted supracondylarly so that the knee joint does not become loose

Period of Immobilization Pin or wire traction must be left until the fragments have firmly united This usually takes 8—12 weeks if no excessive traction was used

Excercises and follow-up treatment are carried out as in fresh femoral fractures (see pages 1204—1208)

Further Treatment in the Plaster Cast If the shortening has been eliminated, a thoracopelvic plaster hip spica can be applied (see pages 1393—1396)



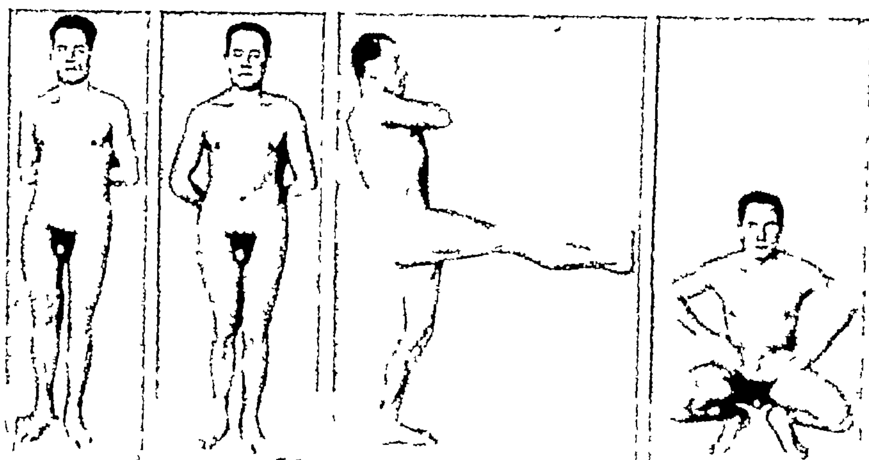
2131, March 7, 1933



2132, March 9, 1933



2133, December 13, 1935



2134
March 7, 1933

2135—2137
October 29, 1936

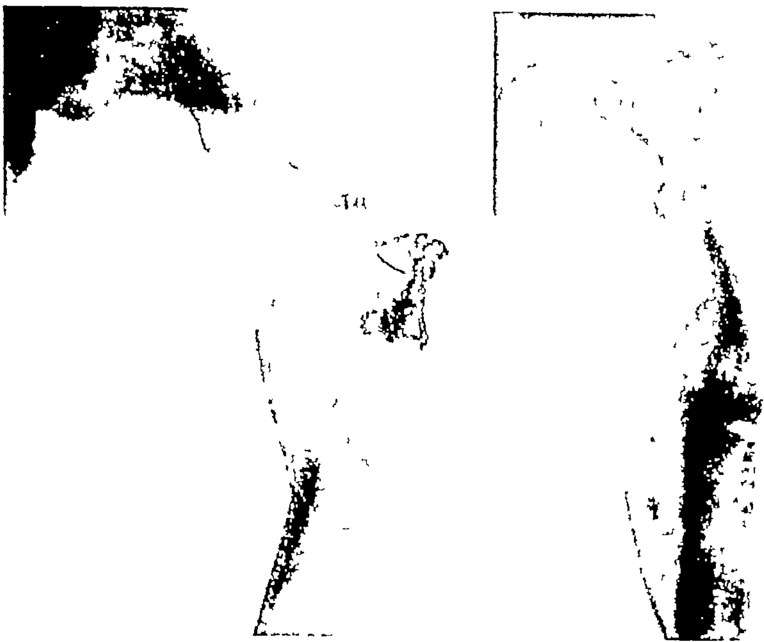
FIG 2131—Eleven week old torsion fracture of the right femur sustained by a 25 year old civil servant who fell while skiing Healed with shortening of 5 cm and varus of 25° The distal fragment was displaced medially by the full width of the shaft Strong callus Patient had been treated by clamp traction weighted with 18 Kg for three weeks, then by a plaster hip spica without thoracic extension for five weeks

FIG 2132—Check roentgenogram re figure 2131, two days after refracture and with the limb in pin traction Shortening and angulation have been corrected Medial displacement of the distal fragment by twice the shaft diameter Further treatment with tibial pin traction for three weeks, then femoral pin traction for another five weeks

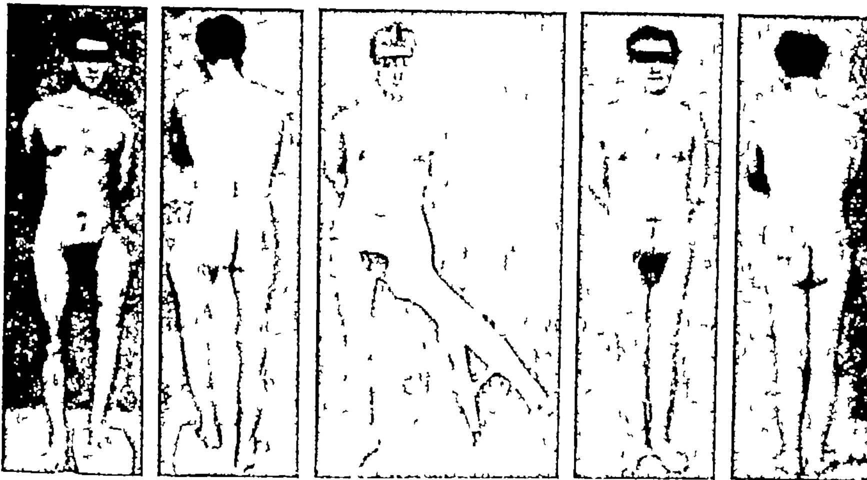
FIG 2133—Check roentgenogram re figure 2132, 2¾ years later Bony union without shortening, good alignment The bone has been remodeled to such a degree that the displacement by twice the width of the shaft is recognizable only by a thickening of the bone

FIG 2134—Photograph re figure 2131 Right thigh bent and shortened

FIGS 2135—2137—Photographs re figure 2133 and comparison pictures re figure 2134, three and a half years later Equal length and equal strength of the bones Right thigh thicker Full range of active motion in all joints No complaints Patient can again participate in sports



2138, February 4, 1936 2139, May 10, 1937



2140 2141 2142 2143 2144
February 4, 1936 July 19, 1936 May 10, 1937

FIG 2138 — Transverse fracture of the femur treated by osteosynthesis Varus of 60°, shortening of 8 cm Big callus bridge medially Broad radiolucent gap at the site of non-union

FIG 2139 — Check roentgenogram re figure 2138, fifteen months later The femur was re-fractured with Schultze's osteoclast and treated by pin traction Five weeks later the plates and screws were removed Then a plaster cast was applied with the limb in strong abduction The fracture united after 13 months with a varus of 10° The fracture line has been bridged but is still visible Now we treat such cases with the medullary nail (M N /figs 735—770)

FIGS 2140, 2141 — Photographs re figure 2138 Severe varus and shortening

FIG 2142 The severe varus deformity could be corrected only by extreme abduction of the limb To make walking possible, a support was applied along the medial side of the lower leg The plaster cast should, as a rule, reach up to the axillae in a fracture of the proximal shaft

FIGS 2143, 2144 — Comparison pictures re figures 2140 and 2141, fifteen months later Fragments united in good position with shortening of 1 cm Atrophy of left lower limb Knee motion 180°—165° A quadricepsplasty was done later with good success

Treatment of Old and Malunited Femoral Fractures by Medullary N

The best treatment of these fractures is by medullary nailing, pr none of the contraindications enumerated in M N/pp 223—225 is p since with adequate nailing no supplementary plaster cast or tract required In the third week after operation, active movements can be s in the joints to overcome impaired motion and to strengthen the n which had been weakened by previous treatment

Before and during operation the following points should be consi (1) The general condition of the patient must be good; (2) The skin mu show inflammatory changes and there should be no deep scars pı



2145 March 14, 1933 2146 July 13, 1935

FIG 2145—Malunited fracture of the distal third of the femur, sustained by a 26 y traveler in a car accident Varus of 10°, posterior angulation of 30°, shortening of 5 cm callus formation Was treated in traction of at first 19 Kg The traction weight was de to 16 Kg 14 days later, and was then further decreased by one kilogram daily s it was only 2 Kg after four weeks Then followed a full leg cast for two weeks, m osteotomy and traction

FIG 2146—Same case two years later Bony union Good alignment in the anteropo view Recurvation of 5° *Dorsal displacement of the distal fragment by a full shaft's*

(3) Shortening of more than 4 cm must be eliminated by continuous tra prior to operation in order to avoid damage to nerves or vessels by su lengthening, (4) A *sufficient* number of blood donors or a blood bank be at the surgeon's disposal, (5) A guide groove of sufficient length shou gouged into both *fragments* to avoid *nailing* with *rotation* defor (6) After introduction of the medullary nail and after impaction o fragments, a wire suture should be placed to avoid *secondary* rot deformity Finally, it is advantageous to add fine bone chips

The operative technique is described in detail in M N/pp 215– Likely causes of failure are listed in M N/pp 223—225

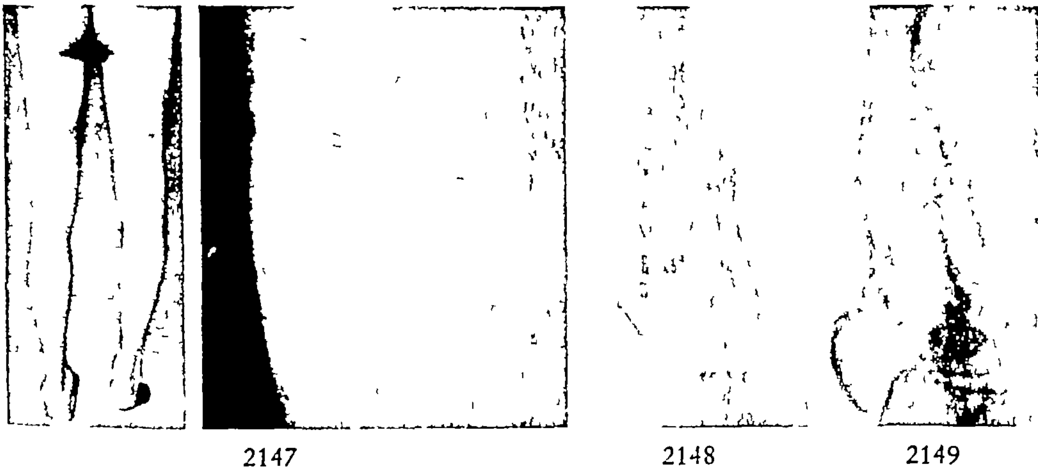
Treatment of Old and Malunited Femoral Fractures with the Three-Fla Nail and Plate or the Angulated Blade-Plate

In fractures near the greater trochanter it is sometimes expedient to three-flanged nail and a plate as shown in figure 2130 The operati described on page 1377

If, in supracondylar fractures, the distal fragment is shorter than 8 cm, the medullary nail will not get a sufficient hold in it For these cases we use an angulated blade-plate as shown in figure 2006 The operation is described on page 1408

71. MEDULLARY NAILING FOR SHORTENING OF THE WELL FEMUR

Shortening of the lower limb may be the consequence of a femoral fracture (figs 2111—2123, and M N/figs 705—734) or of various diseases, e g poliomyelitis, tuberculosis etc Shortening can be overcome by a raised shoe, by lengthening of the short limb or by shortening of the well limb



2147 March 14, 1933 — 2148 January 30, 1933 — 2149 January 7, 1935

FIG 2147—Photograph re figure 2145 Large transverse scar following a pressure ulcer over the projecting central end of the distal fragment Varus, shortening and drop-foot position are clearly visible

FIG 2148—Supracondylar femoral fracture in a 31 year old farmer who was knocked down by a cow The fracture had healed with a shortening of 3 cm The sharp peripheral edge of the proximal fragment projects into the knee joint and interferes with motion of the patella The knee is stiff

FIG 2149—Check roentgenogram re figure 2148, one and a half years later The projecting bone edge was chiselled off Quadricepsplasty was done Present knee motion 180°—100° Patient can walk long distances and can plow all day

Attempts at lengthening of the diseased limb frequently end in failure because the already weakened muscles are thereby further weakened and because delayed callus formation and non-union at times occur Also, infection sometimes develops

We therefore prefer to shorten the sound limb In suitable cases and with correct operative technique, this method yields the better results With poor technique, rotation and even non-union have occured

Determination of the Correct Degree of Shortening The length of each limb, normal and abnormal, is accurately measured After the shortening osteotomy, the sound limb should still be 1 cm longer than the other limb If the operated (sound) limb is shorter than the fractured one, walking is badly impaired, as shown in M N/figs 342 and 343

Determination of the Level at which the Piece of Bone should be Excised In the roentgenogram the narrowest portion of the medullary canal is measured Then the bone piece to be removed is selected in such a way that the two levels of the medullary canal to be apposed after resection are equally wide. If the excision is performed too far proximally, the medullary canal of the proximal piece of the femur is much wider than that of the distal one If the excision is carried out too far distally, the contrary is the case Excision at incorrect levels would endanger final stability

Avoidance of Primary Rotation. When the piece of bone has been excised it is difficult to know how the sawed ends should be apposed correctly Therefore, with a 6 mm gouge we chisel a guide groove into the bone before we osteotomize it This groove should reach at least 3 cm beyond the proximal and distal ends of the piece of bone to be excised.

Excision of the Piece of Bone to be Removed At first the bone is cut at the proximal end of the piece to be removed This is done with a Gigli saw or an electric or pneumatic saw Then the distal fragment is lifted from the depth of the wound and grasped with Lambotte's bone-holding forceps At the previously-marked place, the bone is sawed off transversely As a rule one should not excise more than 8 centimeters

Insertion of the Guide Pin It must be inserted into the proximal fragment along the lateral wall of the medullary canal so that it emerges medial to the tip of the greater trochanter as in figures 2087—2090, 2115, and M N /fig 752 If it is brought out through the lateral side, as in M N /fig 764, a varus angulation as in M N /fig 765 may subsequently develop I had to report a few cases of this kind in which secondary angulation and non-union developed

First Check Roentgenogram To avoid such things, an anteroposterior roentgenogram should be made to ascertain whether the guide pin is located correctly, viz neither too far laterally nor too far medially

Prevention of Secondary Rotation If the roentgenogram shows proper location of the guide pin, a medullary nail the length and thickness of which have previously been accurately determined is driven in as shown in figures 2087 through 2090 a If the ends of the previously-chiseled guide groove are well in line, rotatory misalignment is prevented To eliminate the danger of secondary rotation, holes are drilled transversely through both bone ends, 1 cm distant from the saw-cuts, for fixation of the two ends to one another with a longitudinal wire loop. If the drill holes are placed farther from the ends than 1 cm , the wire loop becomes too long and provides no sufficient protection against rotation

Adding the Excised Bone Formerly we threw away the excised piece of bone Now we saw it into two long pieces which we lay along both sides of the osteotomy site and fix there with two wire loops Callus formation, otherwise slow in transverse osteotomies, is facilitated by this procedure

Time of Getting Up and of Return of Full Strength The patients can usually get up three weeks after operation No supplementary fixation with plaster cast is necessary Muscles, vessels and nerves and the other soft tissues have become relatively too long because of the shortening of the bone The limb is therefore weakened and active extension of the knee is no longer

possible In the course of four to six months, all soft tissues will adapt themselves to the new length of bone, and normal strength and motion will be regained This is demonstrated in figures 2111—2123 and in M N/figs 705 through 734

Questions We Should Ask Ourselves to Avoid Failures in Osteotomy Done for Shortening a Sound Limb

When the circumstances listed on pages 223—225 of M N have been considered, the following questions should also be asked

1 Have I measured the length of both limbs before the operation?
2 Have I determined the length of the piece of bone to be excised so that the well limb remains 1 cm longer than the diseased or fractured one?
3 Have I located the piece to be removed in such a way that the width of the canal is equal on both cut ends?
4 Have I, to prevent primary rotation, gouged out a 10—15 cm. long guide groove?
5 Have I at first cut the bone proximally?
6 Have I inserted the guide pin along the lateral wall of the medullary cavity so that it emerges medial to the greater trochanter?
7 Have I, after insertion of the guide pin, made a frontal roentgenogram of the trochanteric region to check the location of the guide pin?
8. Have I applied a longitudinal wire suture as security against secondary rotation?
9. Have I applied the wire loop to grasp the fragments not more than 1 cm distant from their cut ends?
10 Have I cut through the excised piece of bone longitudinally and then used the two pieces for bridging on two sides the osteotomy site?

72. NON-UNION OF THE FEMUR

Origin. Formerly the main cause of non-union was the extensive removal of bone splinters in open fractures Passive movements and massage started soon after the injury, as in M N/figs 748—753, are a rare cause of non-union of the femur Nowadays non-union usually results from continuous traction with too heavy weights (figs 2111—2123 and 2150—2158, M N/figs 232 through 243, 344—351, 735—747 and 752—783)

It must be particularly stressed that **the aim in the treatment of fractures is to produce an adequate shortening.** Excessive traction causes not only non-union but also the other complications described in Vol I/pp 25—27

Ill Effects of Non-Union of the Femur These patients can usually walk only with the help of braces or two crutches The femur has lost its stability, and there is usually severe limitation of motion in the knee joint and often in the toes and ankle joints as well as severe muscle atrophy and decalcification of the bones

Treatment of Non-Union of the Femoral Shaft with the Medullary Nail

If the general and local conditions of the patient are satisfactory, we usually treat such non-union with medullary nailing When carried out with correct operative technique, it ensures stability so firm that post-operative braces or plaster casts are unnecessary. Union is speeded up by the addition of bone chips With the old methods, in which big bone grafts (M N./figs. 735 until 747) or a single big bone graft with a long metal plate (figs 2153—2158) were used, non-union often developed in spite of good operative technique and a supplementary thoracopelvic plaster hip spica

Preparation of the Bone. Sinuses with sequestra, which often remain after open fractures and occasionally after poorly operated closed fractures, must be dealt with in a bloodless field. Sinuses must have been closed for at least six months and skin conditions must be satisfactory before medullary nailing is performed

Preparation of the Skin Superficial scars or scars adherent to the bone which have remained after healing of sinuses must be thoroughly excised in a bloodless field so that the bone thereafter is surrounded with sound, non-adherent skin After excison of such scars, another three months must elapse before operation in order that the wound healing be firm enough

Bacteriological Examination of the Excised Scar Tissue The excised tissue should be tested bacteriologically just as should the pus from the sinuses Sensitivity of any discovered organisms to penicillin and other antibiotics should be tested

Further Preparation of the Bone Shortening (fig 2150) or angulation (M N/fig 763) may be severe They must be eliminated by pin or wire traction (see pages 1383—1391) before operation, and of course heavy weights must be used In old cases of fibrous union, lengthening may sometimes be impossible in spite of heavy traction weights In such cases the firm adhesions are loosened through manipulation with the Phelps-Gocht osteoclast (Vol I/fig 138) If this does not cause a flare-up of the infection in compound fractures, such a flare-up will probably not follow the nailing either After manipulation, traction with 12 Kg should be applied at once and the traction weight should then be increased up to 15—18 Kg until a slight gap develops between the fragments This usually occurs within a few days. This gap of 5—10 mm. should be maintained for 3—4 days, since it is very hard to loosen the scar tissue as long as there still is a shortening

Correction of Angulation by a Second Pin Traction Subtrochanteric fractures often lead to severe varus angulation, as shown in M N/fig 763. The abductor muscles and the joint capsule are severely shortened laterally Even very strong longitudinal traction fails to correct such angulation As long as the trochanter has not been brought down, the medullary nail cannot be inserted at its medial side In such cases, two Steinmann pins are driven into the lateral side of the femur at right angles to the cortex and at a distance of 3 cm and 4 cm respectively distal to the tip of the trochanter One pin only, as in M N/fig 766, should not be used because a single pin can easily cut through the decalcified bone in which two would hold To set-

screws (Vol I/fig 126) applied to the lateral ends of these two pins is fastened a traction cord which then runs over a pulley fixed to the lateral side of the overhead gallows near the pulley for the longitudinal traction Traction of 5 Kg is exerted then on the cord The severe abduction of the proximal fragment can usually be eliminated within 3—4 days be means of such transverse traction The effect of this transverse traction exerted simultaneously with strong longitudinal traction must be checked by daily roentgenograms, and the pin holes must be inspected daily for the appearance of any skin irritation

Medullary Nailing for Non-Union of the Femur

Preparation of bone and skin are unnecessary after closed fractures of the femur If, however, there was severe infection, operation must of course be deferred until the condition of bone and skin is satisfactory (vide supra, page 1468) When this has been achieved, administration of prophylactic penicillin and/or other anbiotics is begun two days before the operation The operation is if possible performed in a bloodless field. Whole blood infusion is also given The bone is exposed by a lateral incision and a 3—4 cm -long longitudinal guide groove is cut into both fragments with a 6 mm -broad gouge Later these grooves can be brought into line with one another and rotation can thus be avoided The fragments are then exposed subperiostally and freshened according to their shape transversely, obliquely or in a step-cut fashion We usually prefer the transverse saw-cut Then the material filling the end of the medullary canal in each fragment is removed with a gouge or a hand drill The guide pin is inserted into the proximal fragment right along the lateral wall of the medullary canal, as in the shortening osteotomy, so that it emerges just medial to the tip of the greater trochanter (see page 1466) (If the medullary nail is driven in *too* far laterally, as in M N/fig 764, it may cut through the bone as in M N/fig 765) Then the first check roentgenograms are made, and a medullary nail of correct length and thickness can be driven in as shown in figures 2087—2090 a under adequate roentgen control

Additional protection against later rotation is afforded by a longidutinal wire suture as in medullary nail fixation after a shortening osteotomy (see page 1466)

Addition of Bone Chips As callus formation in most cases of non-union is severely delayed because of the poor blood supply to the often eburnated fracture stumps, we now add either autogenous bone chips from the iliac crest or chips from the bone bank about the fracture site This speeds up callus formation and decreases the danger of breakage of the nail (see figures 2113, 2114)

Correction of Shortening After Non-Union of the Femur If the pseudarthrosis has healed with a shortening of more than 4 cm, the sound limb can be correspondingly shortened (see page 1465 and figures 2111, 2123)

Treatment of Non-Union Near the Distal End of the Femur

If the site of pseudarthrosis is within 8 cm of the knee joint, the medullary nail fails to provide sufficient stability In such cases, after preparation of

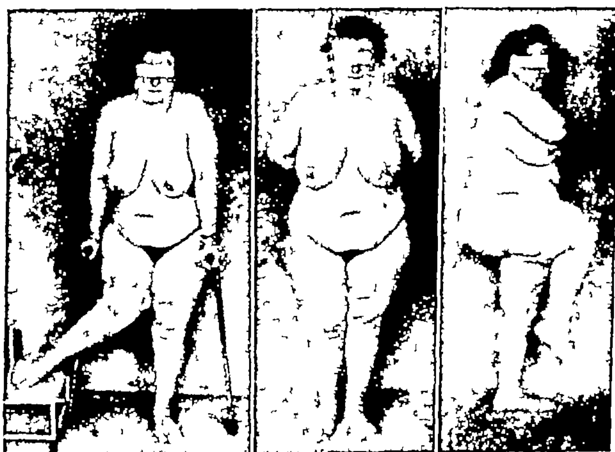


2150, January 10, 1946 2150 a, January 26, 1946 2150 b, March 17, 1948

FIG 2150 —Non-union of right femur following an *open* infected femoral fracture sustained two years previously by a 51 year old landlady (weight 90 Kg, height 165 cm) who fell with her motorcycle Shortening of 5 cm Marked skeletal decalcification Two weeks' pin traction eliminated the shortening Then open medullary nailing was done

FIG 2150 a —Check roentgenograms re figure 2150 The fracture ends were freshened transversely and a medullary nail was inserted The drain lying dorsolaterally was removed after 24 hours The fragments were secured against rotation by a wire suture The patient could walk without external support three weeks after the operation

FIG 2150 b —Check roentgenograms re figures 2150—2150 a, after removal of the medullary nail 26 months after medullary nailing Bony union in excellent position The patient had also broken her patella in a fall



2151, January 11, 1946 2152, March 17, 1948

FIG 2151 —Photograph re figure 2150, before operation showing abnormal mobility

FIG 2152 —Two years after medullary nailing the patient can walk well without a cane Knee motion 160^0—90^0



2153, 2154, May 3, 1946 — 2155, 2156, December 7, 1946 — 2157, 2158, May 24, 1954

A 32 year old post-office official broke his left femur 18 months before admission Immediately after the accident he was treated by continuous traction weighted with 10—20 Kg When non-union had resulted, osteosynthesis with a metal plate and a bone graft was performed Case ultimately seen by Dr Neubauer, Graz, Austria

FIGS 2153, 2154—After operation for fixation with metal plate and bone graft there was good alignment, but a gap is seen between the fragments In the lateral view the shadow of the metal splint is seen dorsal to the femur

FIGS 2155, 2156—Check roentgenograms re figures 2153 and 2154, seven months later In spite of supplementary immobilization in a plaster hip spica for three more months, bony union failed to occur The graft broke, the plate bent, and the screws became loose Varus and antecurvature of 30° each

FIGS 2157, 2158—Check roentgenograms re figures 2155 and 2156, seven and a half years later The metal plate, the bone graft and all screws were removed on December 10, 1946 After freshening of the fragments, a medullary nail was inserted Six weeks later the patient could walk without external support The medullary nail was allowed to remain in the bone, since the fracture line was spanned by only a thin bone bridge For seven years he has done his work as a post-office official

bone and skin as described on page 1468, a medullary nail can be driven through both fragments and then through the knee joint to the region of midshaft of the tibia (fig 2006 b)

Osteosynthesis with an angulated blade-plate, as shown in figure 2005, is a more gentle operation In both methods, bone chips of appropriate size and quality should be added

Treatment of Defect Pseudarthrosis of the Femur

Defects in the femur may be so extensive that they cannot be compensated for completely by a shortening osteotomy on the sound side With good

should show no considerable pathological changes in the bones There must not be extensive scars or swelling The muscles must be strong and the rectus must show good tonus The operation should be performed six months after removal of the immobilizing cast at the earliest, since motion may still be improving without operation until that time We usually operate on patients up the age of 40, only exceptionally up to 50 years of age

Preparation of Skin and Other Soft Tissues Extensive and adherent scars after open, and especially after infected, injuries must be thoroughly excised. The skin must be smooth and freely movable The operation should be performed not earlier than three months after excision of any deep, adherent scars

The Quadricepsplasty should be performed in a *bloodless field,* and there is much bleeding without the use of a tourniquet Formerly we operated without tourniquet and sometimes used dozens of clamps and needed twice as much time for the operation as we do today An incision 20—25 cm long runs from the tibial tuberosity over the middle of the patella up to the middle third of the thigh and severs skin and fascia, which are retracted to both sides The vastus medialis and vastus lateralis are detached with the knife from the patella and rectus tendon for 10—12 cm. and are retracted 3—4 mm of soft tissue should be left along each side of the patella to facilitate subsequent suture The incision must not injure the fat pad, as it bleeds much When one attempts to loosen the rectus tendon and the patella, one sees that the suprapatellar recess is more or less obliterated and that adhesions of varying thickness run from the patella to the femur Patella, tendon of rectus femoris and vastus intermedius are loosened Then the rectus tendon is followed up into the muscle until the whole extension apparatus can freely be raised from the femur. If, after supracondylar fractures, bony spurs protrude into the joint as in figure 2148, they are chiseled off until the surface is smooth, as in figure 2149 With proper selection of the cases and correct operative technique it is never necessary to lengthen the rectus tendon by Z-plasty After having freed all adhesions, one lifts the femur In cases of not-too-long standing the lower leg simply falls into a position of flexion by itself If this is not the case, the knee should be flexed beyond the right angle by slow and careful swinging movements of the lower leg One should not, however, go beyond the flexion angle of 70°, since this may cause rupture of the collateral ligaments or avulsion of their bony points of origin and insertion Sudden or forceful flexion may cause fracture of the patella

Releasing the Tourniquet After flexion of the knee the whole wound is firmly packed When the packs are then removed after 5—6 minutes there is usually very little bleeding if the fat pad was not injured Spurting vessels are clamped but not ligated (see Vol I/p 152)

Suture of the Vasti After hemostasis has been acomplished the knee is flexed to a right angle Both vasti slide 4—5 cm proximal from their original insertions With the knee in this position of flexion they are fixed with towel clamps to the patella and rectus tendon, and then they are later so sutured with the knee in full extension

Insertion of Drains and Closure of the Wound After suture of the vasti, single drains are brought out at the lateral and medial dorso-proximal corners of the wound and each is secured with a stitch The drains must be removed on the next day The suture of fascia and skin is simple in extension of the knee I knew a surgeon who tried to suture the skin in flexion of the knee, and when he failed to do so he resorted to sliding skin flaps

Immobilization of the Leg After application of a compression bandage the limb is placed on a Braun splint Formerly we applied a plaster cast, but the results of the last 15 years have taught us that it is not necessary

Exercises On the Braun splint the knee lies at an angle of 150°. When the patient's temperature has been normal for at least four days, the limb is from the eighth day on placed on an adjustable splint in such a way that flexion will be increased by 10°—15° every day if no pain or swelling develops Thus the angle of 90° is reached in 4 to 5 days For the night the leg is placed again on the Braun splint 14 days after the operation, exercises are started on the knee flexion apparatus (figs 1574, 1575) In the fourth week an Unna's paste boot dressing is applied from the interdigital folds up to the knee joint, and an elastic bandage is put round the knee If passive extension of the knee is impossible, a foot-sling extension weighted with 2—3 Kg is applied for the night Motion of 90° is usually reached after 6—8 weeks, but it may still improve up to eight months For some time we used to manipulate the knee with care under general anesthesia if motion did not seem to improve quickly enough This caused impairment of active extension in three cases We therefore no longer use manipulation flexion under general anesthesia, as it seldom helps and is often harmful

Questions We Should Ask Ourselves to Avoid Failures in Quadricepsplasty

1 Have I operated only on patients in good general condition and under 45 years of age?
2 Have I operated six months after removal of the last immobilizing bandage at the earliest, as up to that time motion can still improve without operation?
3 Have I operated only if there was no swelling of the soft tissue and no bad scars?
4 Have I operated only if the rectus femoris could be contracted well?
5 Have I excised scars before the operation?
6 Have I delayed the operation for three months after the excision of the scars?
7 Have I operated in a bloodless field?
8 Have I avoided cutting into the fat pad?
9 Have I freed well the whole extension apparatus?
10 Have I omitted lengthening of the rectus femoris tendon?
11 Have I flexed the knee with slow and careful movements and not suddenly or with force, to avoid rupture of the collateral ligaments and fracture of the patella?
12 Have I not flexed the knee over 110°?
13 Have I packed the wound before the suture of the vasti?

14. Have I clamped the vasti to the patella and rectus femoris tendon with the knee in 90° flexion and then *sutured* the vasti with the knee in extension?
15. Have I brought out one drain medially and one laterally in the dorso-proximal corners of the wound to be left for 24 hours, and have I stitched each to the skin?
16. Have I sutured the skin with the knee in extension?
17. Have I increased the flexion angle of the splint one week after the operation if there was no fever, no swelling and no pain?
18. Have I had the patient start exercises on the knee flexion apparatus 14 days after operation?
19. Have I applied an Unna's paste boot dressing and an elastic bandage after three weeks?
20. Have I applied foot-sling traction with 2—3 Kg for the night if passive extension of the knee was not complete?

End Results of Quadricepsplasty

We have operated about 80 cases Trojan [1] re-examined our 39 cases with 40 knee joints (1 bilateral case) which were operated on within the 13 years from 1939 to 1951 inclusive Of the 39 patients, 33 reported for the follow-up examination. 21 patients (63 7%) showed a very good result They could flex *beyond the right angle and had full extension or a loss of extension of less* than 10° Figures 2215—2224 show such a patient operated on in 1932 who has full usefulness of his limb Only 4 cases (12 1%) had a range of movement of less than 60° and a loss of extension of as much as 30°

End-Results of Treatment in Closed Fractures of the Femoral Shaft

We have treated a total of about 1200 closed fractures of the femur. Of these, 81 cases from the years 1916—1918 and 226 cases from the years 1926—1935 were observed for a sufficiently long time and were critically re-examined

Amongst the 81 cases from the first period, 66 healed with a shortening of 0—0 5 cm, 5 with a shortening of 0.5—1 cm, and 10 with a shortening of 1—2 cm The average shortening was 0 2 cm

Toes, ankle and hip showed free motion in all patients The knee flexion was less than 90° in only four patients These four patients were all younger than 50 years

Deaths Of the 226 patients from the years 1926—1935, 11 (3 92%) died during treatment, viz, *four from senile marasmus* (ages 78, 87, 87 and 94 years), three from severe concomitant injuries and one case each from malignant metastatic growth, ileus, fat embolism and pulmonary embolism

Shortening In the 215 survivors the average shortening was 0 3 cm The shortening was never more than 2 cm In 1936, however, we had one case with a shortening of 3 cm

[1] Trojan, E Verhandlungen der 18 Tagung der deutschen Gesellschaft fur Unfallheilkunde, 1954

Incapacity Pensions Of the 226 patients with closed fractures of the femur, 102 patients were insured 14 (13 73%) drew a permanent incapacity pension 7 of these received pensions because of simultaneously incurred severe injuries, and the other 7 patients are all older than 58 years of age

All the 14 insured patients with femoral fractures from the year 1927 were re-examined and photographed in 1929 and again in 1934 To give a report which can be examined by everybody and at all times, these cases were published together with all roentgenograms made both before the treatment and at the time of re-examination, and with photographs. The case histories, containing all important data about profession, age, cause of the fracture, kind and period of treatment, shortening, motion of the joints, the patient's wages before and after the treatment and at later periods as well as the amount of the incapacity pension, were also given For comparison, the 18 cases of femoral fracture insured with the Worker's Accident Insurance Company and treated in 1927 in hospitals other than the Vienna Accident Hospital were examined and reviewed [1]

The average shortening among cases treated in the Accident Hospital was 0 3 cm , the average for those treated outside the Accident Hospital was 2 15 cm

Toes, ankle and hip were freely mobile in all 14 cases from the Accident Hospital, the knee was freely mobile in nine cases Only one patient was unable to flex the knee at least 90°

There were no cases of flail joints

The *average period of treatment* in traction or in plaster was 72 days

The following table shows the average period of treatment till the resumption of manual work, the permanent incapacity pension, the loss of working days and loss of wages

	Average period of treatment in days	Percentage of patients drawing a permanent pension	Number of lost working days	Loss of wages in Austrian Schillings
14 cases treated in the Accident Hospital	240	10 2	627	5016
18 cases treated elsewhere	390	22 6	1819	14552

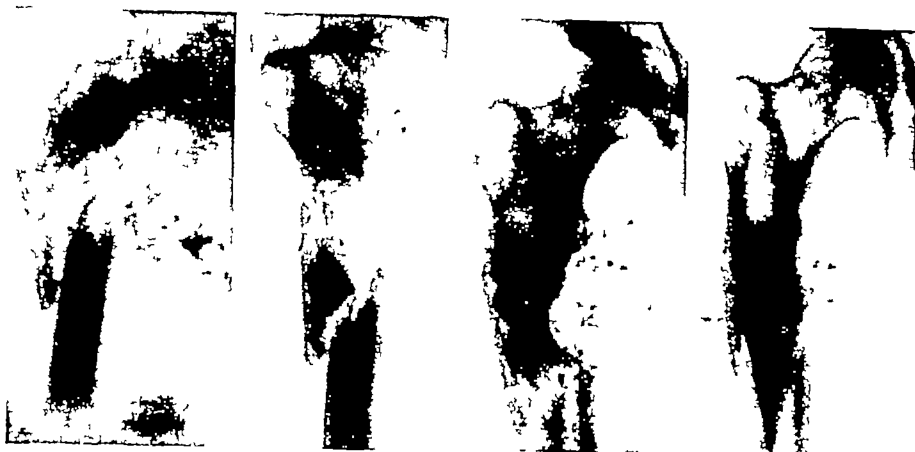
The end-results are perhaps best demonstrated by figures 2165 and 2166

End Results of Fresh Open Fractures of the Femur

Ehalt in his book [2] has described in detail our 23 cases treated in the nine years 1926—1934 Of all these patients, the roentgenograms made before

[1] Bohler, L Die Behandlungsergebnisse der Oberschenkelbruche Arch f orthop Unfall-Chir *35* 466—510, 1935

[2] Ehalt, W Die Behandlung der offenen Bruche der langen Rohrenknochen mit Einschluß der Behandlungsergebnisse, Vienna, Maudrich, 1938



2159 July 15, 1927 — 2160 August 1, 1927 — 2161 January 22, 1928 — 2162 June 14, 1952



2163—2164, May 14, 1929

FIG 2159—Subtrochanteric gunshot fracture of the femur sustained by a 28 year old unskilled laborer Marked shortening, varus, lateral displacement and external rotation Considerable loss of bone and soft tissue The light area between the fragments is caused by air in the tissues Multiple metal splinters are seen medially

FIG 2160—Check roentgenograms re figure 2159, 17 days later After excision of the big wound, longitudinal traction was applied All displacements have been corrected The gap resulting from loss of bone which was shot away is seen

FIG 2161—Check roentgenograms re figures 2159 and 2160, six months later After four months' continuous traction (three weeks by tibial pin, five weeks by femoral pin, eight weeks by Unna's paste dressing) the bone has united without shortening and the gaps in the bone have filled with dense callus The course of the muscles can be traced by noting the position of the fragments of metal before and after reduction The wounds had healed and all joints had regained full motion after six months

FIG 2162—Check roentgenogram re figures 2159 and 2160, 25 years later The gap in the bone has filled with bone

FIG 2163, 2164—Photographs re figures 2159 and 2160, after two years A big transverse scar is visible below the gluteal fold The two lower limbs are equally strong Full range of active motion in all joints

treatment and at the time of re-examination are shown, as well as photographs demonstrating shape, strength and motion of the limb

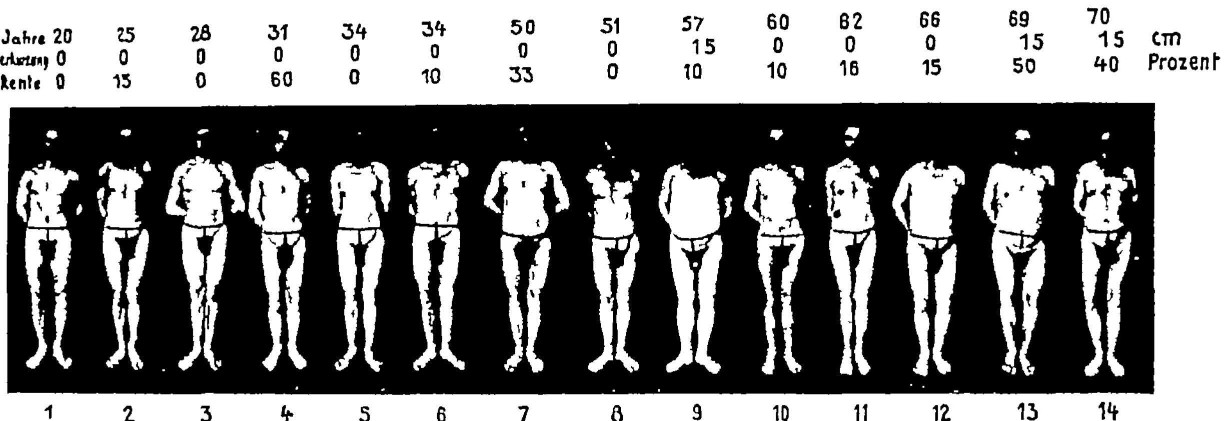


FIG 2165—Fourteen cases of femoral fractures treated at the Vienna Accident Hospital in 1927 (accident insurance cases) Age, amount of shortening and compensation received two years after the accident are indicated above each case

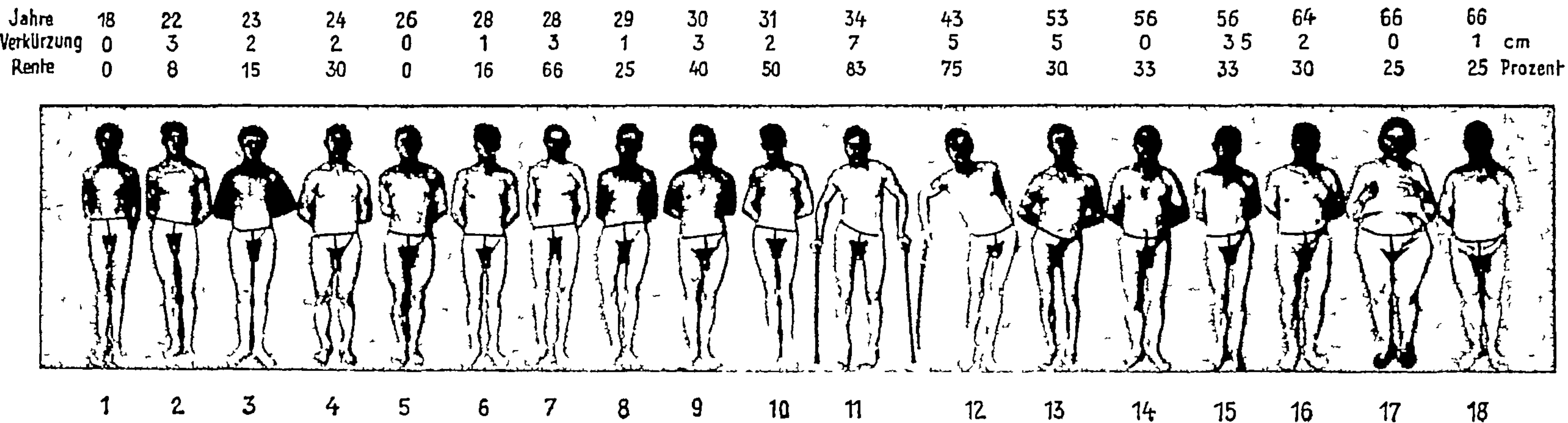


FIG 2166—Eighteen cases of femoral fractures treated elsewhere (accident insurance cases) Age, shortening and compensation received two years after the accident are indicated above each case

Deaths Of the 23 patients, three died, viz one immediately after admission as a result of the severe injury, the second from cerebral embolism and the third from sepsis originating not from the open fracture of the femur but from another injury

Of the 20 survivors, 18 healed without one drop of pus The 2 patients with gunshot fractures, whose wounds were purposely not sutured, healed by granulation without inflammation or rise of temperature (figs 2159—2164). As all cases healed without infection, no sequestra and *no sinuses* developed

Non-union resulted in two cases because of *excessive traction* After bone suture and bone grafting, these cases healed with bony union

Shortening Of the 18 cases which united without operation, none had a shortening of more than 0 5 cm Most cases healed without shortening

Motion Toes, ankle and hip were freely mobile in all cases The knee joint was free in ten cases, and in seven cases it could be flexed to 90° One patient could flex his knee only 50°, the knee was stiff in the two cases of non-union

Flail joints did not develop, though the knee joint was exposed by the injury in eight of the 20 survivors

End-Results of Medullary Nailing in Femoral Fractures

Jörg Bohler (see page 1441, footnote) published the end-results of our 151 femoral fractures from 1941 to 1948 treated with a medullary nail Among these were *61 closed fractures of the femur* Hospitalization lasted an average of 45 8 days in cases with concomitant injuries and only 30 days in those without concomitant injuries, as against 117 days with such fractures treated by traction

Of the *26 open fractures of the femur* treated by medullary nailing, two died on the day of the injury Among the 24 survivors, one patient had a slight infection which healed without permanent disturbance

Contrary to the findings in the cases described earlier by Ehalt, there was no case of non-union

One case of extensive comminution similar to that shown in figures 2107 and 2108 had a shortening of 6 cm, because we did not risk using a supplementary wire loop in the pre-penicillin period Four more cases had shortening of 0 5—2 cm and each of the other 19 had less than 0 5 cm

Motion of the Knee Joint It was free in 17 of 24 cases (71%) as against 10 out of the 20 cases (50%) reported by Ehalt

74. GUNSHOT FRACTURES OF THE FEMUR

General Considerations

Frequency Gunshot fractures of the femur stand third in frequency in Jimeno Vidal's statistics and fourth in ours They are distributed as follows

	Gunshot Fractures of the long cylindrical bones	Gunshot Fractures of the Femur	Percentage
Jimeno Vidal 1936/39	2563	600	23 4
Bohler 1916/18	601	111	18 6
Exner 1912/13	280	65	23.2

Site of Fracture Jimeno Vidal had 135 (22 5%) gunshot fractures in the proximal end without involvement of the joint, 258 (43%) in the shaft, and 137 (22 8%) in the distal end without involvement of the joint Besides, he had 70 (11 6%) incomplete gunshot fractures

Type of Fracture Among 530 complete fractures, 392 (73 9%) were severely comminuted, 49 (17 9%) were oblique and 44 (8 2%) were transverse fractures The zone of comminution often extended up to 20 cm Jimeno

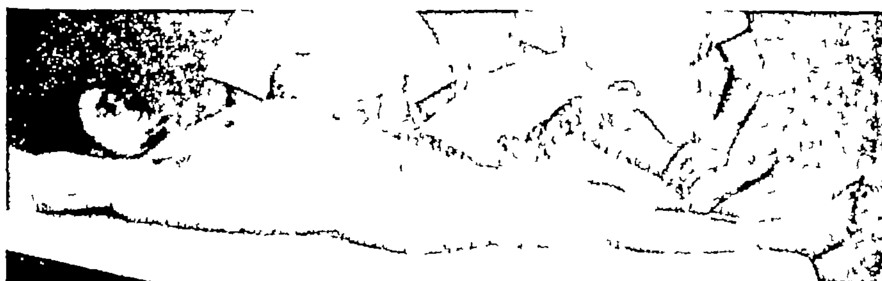


FIG 2166 a —Holding a patient with gunshot fracture of the femur for application of a cast With the forearm placed in the popliteal region, one exerts traction which is supplemented by the pressure of the other hand on the ankle A nurse holds the thigh and prevents the fragments from sagging

Vidal observed one case with comminution over 35 cm The incomplete fractures were mostly grooved or "buttonhole" fractures in the proximal or distal end But he also observed clear-cut "buttonhole" fractures of the shaft

The *displacements of the fragments* are similar to those in closed fractures

Injuries to the Nerves Among the 600 gunshot fractures of the femur, 40 (6.6%) had injuries to the nerves, whereas these are observed in 29 1% of gunshot fractures of the humerus and in 14 5% of gunshot fractures of the forearm

Injuries to the Vessels Most injuries to the main artery lead at once to death from bleeding The hemorrhage may, however, stop by itself Besides the injuries to the main artery, injuries to the deep branches also may cause severe hemorrhage Infection may cause the blood clot which obstructs the wound of the vessel to soften and liquify, and dangerous secondary hemorrhage may follow Among the 600 cases, 18 (3%) cases of secondary hemorrhage due to sepsis were seen

Kind of Wounds Of the 600 gunshot fractures of the femur, 128 (21 3%) had small through-and-through wounds, 222 (37%) medium-sized, 37 (6 1%) irregular, 103 (17%) extensive through-and-through wounds, and 110 (18 4%)

had lodging gunshot wounds. Besides the 110 lodging gunshot wounds there were 46 cases in which metal splinters remained after a through-and-through gunshot wound.

In gunshot fractures of the forearm only 10.1%, and in those of the humerus 13%, lodging gunshot wounds were observed.

TREATMENT OF GUNSHOT FRACTURES OF THE FEMUR

First Aid, and Treatment at the Main Clearing Station

Treatment of shock, analgesia, warming, protection from tetanus, and administration of penicillin are carried out in the same way as in gunshot wounds of the hip joint (see pages 1143 and 1144).

How to Hold the Injured Limb for Applying the Wound Dressing and the Transport Dressing. If the fractured limb is lifted at the heel the fracture will sag and wounds on the concave side of the sag cannot be approached in spite of traction on the leg. Besides, such handling is very painful. The wounds can be approached and inspected best if an assistant slips his forearm into the popliteal region and grasps the anterior side of the ankle with the other hand. Then the knee should be slowly and carefully lifted and pulled while the lower leg, held down by the assistant's other hand, acts as a lever. Thus a gentle traction is exerted on the fractured femur and gross displacement is reduced. The thigh can be approached from all sides and dressings and splints can be applied without considerable pain. If the thigh still sags in spite of this traction, a second assistant should support the proximal fragment from the well side with his hand without touching the wound (fig. 2166 a).

Bleeding is arrested as in gunshot wounds of the hip joint (see page 1144).

Esmarch's tourniquet must not be applied before long transportation, since the limb may become necrotic if the tourniquet remains in place for more than two or three hours. In winter, severe disturbances from cold may develop in a ligated limb within a very short time indeed. Impeded circulation also facilitates the development of gas-gangrene. Besides, the tourniquet is very painful. We have often observed that a tourniquet has been applied but not tightened sufficiently, so that it actually caused congestion and increased hemorrhage.

The bandage for transportation to the main clearing station, to the field or base hospital is applied in the same way as in gunshot wounds of the hip joint (see page 1144).

The use of a *sheet metal boot* splint for a gunshot fracture of the femur *must be avoided,* as it reaches only to about the fracture site in fractures of the proximal shaft. Even fractures of the distal shaft are not immobilized by this splint. The patients are only encumbered by such a splint and are worse off than before, as the part of the limb distal to the fracture has become heavier. Moreover, patients with these splints are often handled less carefully because they appear to be well immobilized. Amongst the some 100 patients with gunshot fractures of the femur which I admitted at the main clearing station from 1914 to 1916, many were brought in with that splint. Even in World War II I saw it often.

Questions We Should Ask Ourselves To Avoid Failures When Treating Gunshot Fractures of the Femur at the First Aid Post and at the Regimental Aid Post

Besides the questions enumerated for gunshot wounds of the hip joint (see page 1145), the following questions should also be asked

1 Have I applied no Esmarch tourniquet before long transportation?
2 Have I applied no sheet metal boot splint in the case of a gunshot fracture of the femur?

Treatment at the Main Clearing Station, Field and Base Hospitals

Application of Warmth and Treatment of Shock. Most patients with gunshot fractures of the femur suffer from loss of blood and shock They must be covered with warm blankets and should be given hot drinks and analgesics Sometimes transfusions of plasma or blood are needed The patients should be uncovered as little as possible for redressing and cleaning the wound and for applying splints What should be avoided has been described in Vol I/p 136

Cleaning the Wound With the Scalpel When shock has abated, motion and sensibility are tested, as are also the dorsalis pedis and the posterior tibial pulses Largely on the basis of these findings, one must decide whether the limb can be preserved or must at once be amputated Through-and-through wounds with small wounds of entrance and exit must never be exised Neither should these wounds be closed by sutures, since this would cause tension in the tissues and increase the danger of infection In large through-and-through wounds and in lodging wounds, all torn, soiled and devitalized tissue must be cut away if possible under *local anesthesia* But no sound tissue at all should be sacrified By this careful wound débridement most of the pathogenic organisms and especially their "breeding ground" are removed The excision of the wounds should be carried out according to the rules given in Vol I/pp 142—174, though one will seldom be able to do it so painstakingly It must be thorough and should be performed quickly to avoid much bleeding The arrest of bleeding must be complete Rubber drainage tubes are placed at the most dependent site and fixed with sutures One drain must under all circumstances be inserted dorso-laterally, another one may sometimes be necessary medially, as shown in Vol I/figs 244—246 Spreading cellulitis can thus be avoided The wound cavity should not be packed with gauze, since this would lead to retention of pus The large, grossly lacerated wounds in thick muscles of the thigh are very liable to the development of gas-gangrene if they are not adequately cleaned with the scalpel In the case of severe infection, wide exposure must be carried out Besides, penicillin is given together with, if necessary, other antibiotics

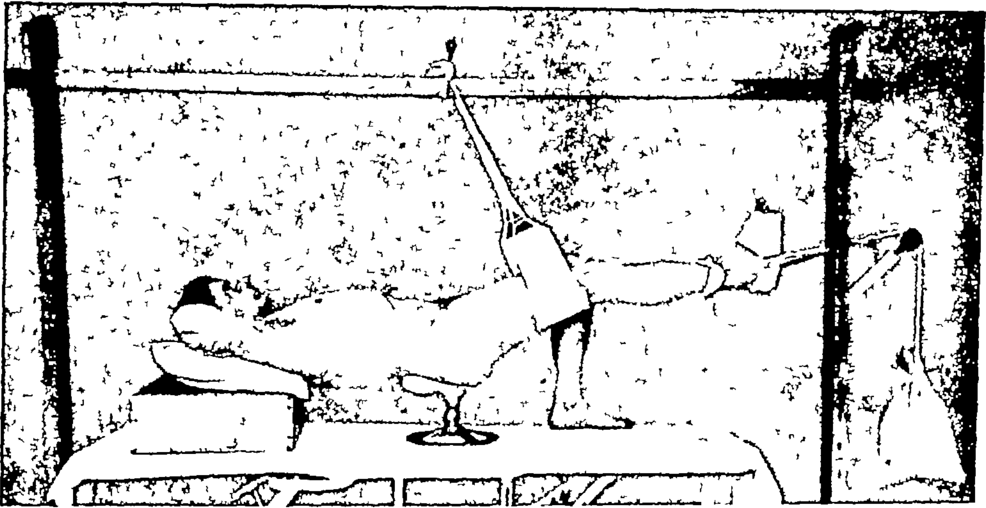
Figures 2159—2164 show what can be achieved by thorough débridement with the scalpel This man was admitted to our hospital two hours after the injury The exit wound in the buttock was bigger than a fist After immediate excision of this wound, pin traction was applied

The suture of severed nerves can seldom be considered

Bone splinters must not be removed This would lead to defect pseudarthrosis

Contrary to the situation in peace-time injuries, the excised *wounds must not be sutured*, since this might lead to the severest wound infection and gas-gangrene

Amputation should be performed quickly if the main artery is certainly severed or if it is thrombosed, if the foot is without pulse, without sensibility, and is cold Amputation should also be carried out in cases of huge defects of skin or soft tissue, in large wounds with simultaneous severance of the sciatic nerve, and in open, severely-comminuted fractures of the knee joint with large soft tissue wounds Gross comminution of the bone distant from the joint is in itself no indication for amputation



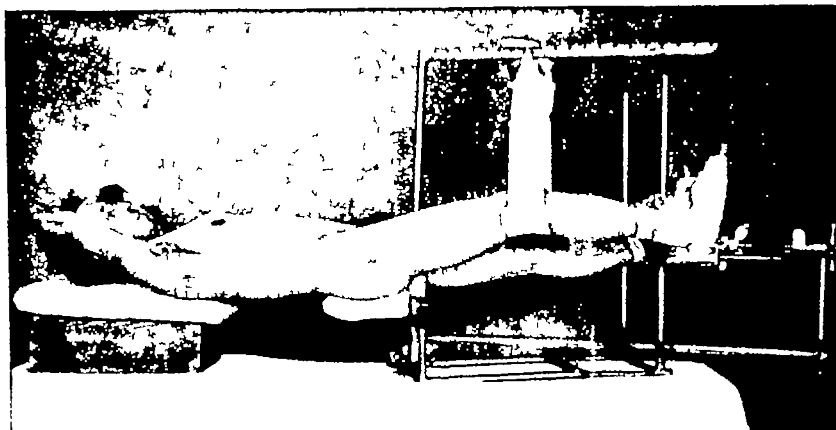
August 1916

FIG 2166—Positioning of a patient with gunshot fracture of the femur for application of transportation plaster cast with slight flexion of hip and knee The pelvis rests on a pelvic support, thorax and head rest on a wooden box A gallows as used for femoral fractures is set up over the operating table Foot-sling traction with a sand bag weighing 6—8 Kg is shown The site of fracture is secured against sagging by a padded suspension sling

Performance of Amputation It should be performed in a bloodlees field. In amputation through the upper third of the femur, a Steinmann pin should be driven into the greater trochanter This allows one then to apply the tourniquet below the inguinal ligament An anterior and a posterior flap are made and are turned back and each is fastened by a loose suture Circular amputation should only be performed in gas-gangrene when a speedy operation is indicated After development of the flaps, the vessels are clamped The nerve must not be pulled distally, then cut It would, of course, then retract and might cause a tubular abscess within its sheath which I have often seen at post-mortem examination in such cases The periosteum must not be dissected off but must be cut at the level of the saw-cut through the bone The bone-marrow should not be scraped out if one would avoid ring sequestra and painful periosteal reactions The amputation wound must not

be closed by suture. As soon as the surface of the wound has become clean (this occurs sometimes within one week), longitudinal traction with a stockinet tube is applied in order to prevent too marked soft-tissue retraction The tube is secured to the skin with Mastisol or Unna's paste and should not, of course, be spread by a ring. The traction is weighted with 2—3 Kg If no necroses develop, secondary suture can sometimes be performed after only three weeks

If one is in doubt as to whether or not the limb can be preserved, it is best to place it on a thigh splint (figs 1605—1607) and to apply a tibial pin or wire traction weighted with one-tenth of the body weight Traction and correct positioning will reduce the fracture In fractures of the distal third of the femur, eventual pressure of the distal fragment on vessels and nerves (Vol I/figs 242, 243) will then cease If the patient is warmed and receives plasma or blood in the case of severe loss of blood, one will sometimes be



January 1927

FIG 2166 c—Positioning a wounded patient with gunshot fracture of the femur on the screw traction apparatus for application of a transportation plaster cast in slight flexion of the hip and knee Foot-sling traction of 6—8 Kg is exerted by means of the screw Slight flexion of hip and knee is effected by a sling supporting the knee Recurvation of fragments must be corrected by pressure on the dorsal side of the thigh exerted with the flat of the hand during application and setting of the plaster cast

happy and gratified to see that the limb becomes warm again and the dorsalis pedis and posterior tibial pulses are again palpable If the limb remains cold and without sensibility, amputation should no longer be postponed

Avoidance of Wound Infection and Affordance of Freedom from Pain By Uninterrupted Immobilization The best way to avoid wound infection and permanently to relieve pain after thorough excision of the wound is to afford complete, never-interrupted immobilization of the whole leg in a thoraco-pelvic plaster hip spica (see pages 1214—1223) Penicillin and other indicated antibiotics should be administered at the same time

Bandage for Transport to the Special Army Hospital

The best transport bandage is the padded and fenestrated thoracopelvic plaster hip spica In fractures of the distal third of the femur the cast must

extend up to the costal arch (fig 2166 d), in fractures of the middle or proximal thirds it must extend up to the axillae All dressings used for the purpose of immobilisation but which do not include the hip joint do not really immobilize the fracture fragments and must therefore be rejected The cast can be applied without causing pain after an injection of Scopolamine-Eucodal-Ephetonine has been given

Positioning the Patient for Application of the Transportation Cast During World War I we used to apply a gaiter (fig 2166 b) or a well-padded sling to the foot The patient was placed on a pelvic rest, and a padded wooden box or package of bandages was placed to support his thorax A wooden gallows, which we carried with us, was set up over the operating table Then hip and knee were slightly flexed by suspending the femur at the fracture site with a padded sling This eliminated the recurvation present in most fractures of the middle and especially of the distal third The foot sling or gaiter was weighted with 5—10 Kg With more traction the suspension sling would have a constrictive effect on the soft parts To avoid this it is better to apply this suspension sling at the popliteal region as shown in fig 2166 c.

In applying a transportation plaster cast it is not important to have the fragments completely reduced Residual shortening or lateral displacement are of no account Besides, shortening is never great in fresh cases Marked shortening develops only later with inadequate treatment Angulation, however, should be corrected as much as possible to avoid formation of big cavities where pus can collect (Vol. I/fig 242) All cases immobilized in extension showed a marked recurvation and some a peroneal nerve paralysis which developed after application of the cast and disappeared when the pressure on the nerve was released by correction of the angulation

Application of the Plaster Cast After sufficient padding, the plaster cast is applied as described in figures 1627—1640 with the one exception that hip and knee are slightly flexed The varus can easily be corrected if the limb is slightly abducted after application of the pelvic part Excessive abduction, however, must be avoided lest the cast be very awkward to handle and difficult to transport

Fenestration of the Plaster Cast Before application of the plaster cast the wounds ar covered with sterile dressings which should overlap the margins of the wounds by only 2—3 cm The dressings are fixed with Mastisol and adhesive tape Then tubular rings 2—3 cm deep and in circumference the size of the wounds are made of cardboard or sheet tin bands and are placed over the dressings With these "rings" placed over the wounds the plaster bandages can be carried round them and the time-consuming and difficult cutting-away of plaster is avoided Moreover, the cast is not weakened as is often true when "windows" must be cut During transportation the wounds can then be inspected and re-dressed if necessary without any interruption of the immobilization

If there is the danger of a spreading infection, very large windows are cut and bridged by iron bands Spreading of the infection mostly occurs ventrally and laterally The band of a walking iron is therefore inserted dorsally, extending from the hip to the popliteal region, and the ventral or lateral half

of the thigh part of the cast, or even the whole thigh part of the cast down to a 10—15 cm -broad dorsal band, is removed If large wounds lie dorsally, a band of the cast is left at one side and reinforced with the iron band of a walking caliper. Ventrally and laterally sufficiently-high iron bands bridge the hip and knee regions (fig 2166 e) Thus the immobilization of the fracture fragments and the whole limb is maintained, the whole wound region can easily be surveyed, and drainage incisions can be made if necessary

Application of the Plaster Cast With the Patient in the Screw Traction Apparatus Vidal reported that 342 (64 5%) of his 530 complete gunshot fractures of the femur were admitted with a plaster hip spica which had been applied on a screw traction apparatus, as shown in figures 2166 c, d Most mobile Spanish war hospitals had this apparatus with them Since transportation took a relatively short time (the hospital was about 150 miles behind the front), the casts were applied unpadded, not fenestrated, and not split He never saw any harm done by this It is, however, more expedient and safer to split unpadded casts before transportation

All wounded men with fresh plaster casts must be kept warm after application of the cast and during transportation

Splint Bandages In the first years of World War I, when we generally had no plaster-of-Paris, we used to apply splint bandages In mobile warfare in Galicia, in the battles on the Isonzo river and in the Dolomites, I immobilized about 400 gunshot fractures of the femur with splints made from cardboard and reinforced with wooden laths

Padding of the Splints Splints of wood, tin or wire may be applied only if they are sufficiently padded Cloths are hardly suitable for this padding, as they usually are much soiled and hard from blood Fine wood-wool or "excelsior" proved best as padding material in more than 3000 fractures and gunshot wounds of the joints After the outbreak of hostilities in August of 1914 I had wood-wool pads made whenever there was a lull in the fighting They were 12, 18, 25, and 35 cm wide and 10 meters long, and they were made in the following way 33-thread calico, or 18-thread gauze, of a little more than twice the width of the required pad was spread on a table and on it the wood-wool, uniformly arranged, was laid in a thickness of about 1—2 cm Then the calico or gauze was folded over and sewed up with long stitches The whole was preserved in 10 meter-long reels Whenever necessary, a piece of the required length was cut off It is the great advantage of the wood-wool that it is highly resilient and absorbs wound secretions well Sewn up in the calico as it is, it cannot shift or form into a ball, things which easily happen with cotton or cellulose padding if it is not carefully sewn

Positioning the Patient on Wooden Trestles To avoid having to kneel down for examining and dressing wounds we always carried 70 cm -high wooden trestles with us on which stretchers were placed In this way the wounded soldier is spared the painful shifting to the operating table Whenever a dressing had to be applied to the pelvis we placed a wooden board on two trestles and put the stretcher on the board This lifted the patient out of the trough formed by stretcher's canvas so that he became easily accessible

In this manner any number of operating tables can be constructed quickly and without difficulty at every dressing-station. The pictures illustrating this I published in 1916.[1]

Preparing the Splint The wounds were not dressed until the splints had been prepared and padded as required For gunshot fractures of the femur at that time I used almost exclusively splints of cardboard reinforced with a wooden lath First we cut out a piece of strong cardboard 145 cm long and 20 cm wide with at one end a 20 cm wide cross-piece for the patient's pelvis This was covered with a 25 cm broad pad of wood-wool For the rear of the cardboard splint was reinforced with a wooden lath 120 cm long additional strength Woodwool pad and board were fixed to the cardboard splint by means of a roller bandage Then the length of the sound limb was measured Two lateral incisions were made near the splint's distal end which was then turned up to form a sole A flat, somewhat wedge-shaped bundle of woodwool, 20—25 cm long and 5—10 cm thick, was placed into the popliteal space to achieve slight flexion of the knee, and another, smaller one was put underneath the Achilles tendon to protect the heel from pressure.

Applying the Splint As soon as the wounds were dressed the wounded soldier was told to flex hip and knee of the sound limb to assist us in transferring him to the pelvic rest Then the splint complete with padding was pushed under limb and pelvis Wood-wool pads of suitable width were placed on the ventral side of foot and limb and on the abdomen and were fastened by means of roller bandages Beginning just above the ankle-joint and passing round the foot in figure-eight turns, the roller bandage was taken round the instep in at least two circular turns so that the dressing could not work loose and the foot fall laterally The toes must remain free Then the roller bandage was taken upward and round the pelvis in figure-eight turns For this purpose at least two strong roller bandages of 10 meter length and 15 cm breadth are required. Plaster bandages had to be applied on top of them to prevent them from furling and slipping The wound sites were left unpadded so that later no windows needed be cut over them Only after the plaster had been applied were ample cellulose or surgical cotton dressings put on the wounds

I have given such a detailed description of this dressing because even today it is not always possible to apply plaster casts In World War II we often used the board-and-plaster bandage as described by Scheiblinger He applies a wooden splint (2 × 12 × 120 cm) without cardboard after suitably padding the pelvis, popliteal space and Achilles tendon For immobilization of the foot he uses a Cramer splint The board is placed on two bricks when it is applied

Fenestration of the plaster cast is carried out in the manner described in Vol I/p 609 For inscription of the cast see page 1148

Time of Evacuation After the wound has been cleaned with the scalpel, penicillin given and an appropriate transportation bandage applied, the

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[1] Bohler, L Transportverbande fur Schußfrakturen und Gelenkschusse in der vordersten Linie Med Klinik, 29 1916

patient given some refreshment and restorative and protected from chilling by warm blankets and, in very cold weather, by hot-water bottles, he should at once be evacuated to a special hospital for gunshot fractures and for gunshot injuries to the joints as fast as possible, preferably by air and *without any stopover* He should remain in that special hospital *without interruption* until he is completely healed

Particular emphasis should be laid on this point, since time and again the theoretical demand has been made that gunshot fractures of the femur be treated at the place of the first surgical treatment for 1—3 weeks "until the power of the infection has been broken" In practice, however, I have never seen that such a rule has been observed in the course of major military operations, for the simple reason that there was no room for such cases in the advance hospitals Besides, the advance hospitals are often under fire, a fact which is understandably likely to make seriously wounded people immobilized in traction very nervous indeed

It has also been demanded that the soft-tissue wounds be treated first until the infection is overcome, and only then the bones In reply to this it must be said that the treatment of wounds of the soft tissues and that of broken bones cannot and must not be separated from each other The best treatment of any soft-tissue wound is its closure followed by complete, uninterrupted immobilization Inflammation will then subside very quickly The same applies to the broken bone By eliminating the worst displacements and angulations one eliminates those cavities in which pus might accumulate and relieves blood vessels and nerves of harmful pressure (Vol I/figs. 242 and 243)

Medullary nailing should be considered only in very favorable circumstances as described and shown in M N /pp 197—211 and figs 651—683

Questions We Should Ask Ourselves to Avoid Failures When Treating Gunshot Fractures of the Femur at the Main Clearing Station and at the Field and Army Hospitals

Besides the questions for gunshot wounds of the hip joint (see page 1148), the following questions should also be asked and answered

1 Have I always included the hip in the cast?
2 Have I omitted using a sheet metal boot splint for transportation?
3 Have I split unpadded plaster casts for transportation?

Definite Treatment of Gunshot Fractures of the Femur in Special Army Hospitals

The treatment of shock, the preliminary retention of the immobilizing transportation bandage and the question as to whether the wounded should be further treated by plaster cast or in continuous traction are dealt with in the same manner as in gunshot wounds of the hip (see pages 1149, 1150)

Treatment of Aseptic Gunshot Fractures of the Femur

If roentgenograms show the fragments to be in good position and alignment, and if the transportation cast is in good condition, that cast is

allowed to remain Otherwise the cast is removed, the limb is carefully placed on a Braun splint and pin or wire traction is instituted as in the case of fresh, closed femoral fracture (see pages 1383—1391 and figs 1604—1608)

Treatment of Infected Gunshot Fractures of the Femur

Most gunshot fractures of the femur are infected Jimeno Vidal reported 70 per cent of his cases to be infected, Bohler 83 per cent and Franz[1] even 90 per cent

Infection is extraordinarily dangerous In the Crimean War (1854—1856), 86 per cent of the patients with such infection died from it, while in World War I the mortality was at first 80 per cent and then later 42 per cent (Franz) Moreover, many such patients had to have the limb amputated (statistics in Vol I/p 280). In the survivors there were many non-unions, great shortening up to 25 cm (figs 2166 o, p), angulation, rotation, severe limitation of motion, flail knee joints, drop foot, pressure ulcers about the heel, and flexion contractures of the toes, expecially of the great toe With the exception of the limitation of the knee motion, which is in some cases unavoidable, all of these things can be avoided by the use of well-chosen and well-planned treatment

In the treatment of every infected gunshot fracture of the femur it is most important to secure **evacuation of pus and complete, uninterrupted immobilization of the fractured limb.** Exercises of all joints not included in the plaster cast must not be neglected In addition, penicillin and other antibiotics are given until the temperature has been normal for 4—5 days

Treatment of Infected Gunshot Fractures of the Femur by Continuous Traction If the transportation bandage does not fit well, if extensive inflammation is detected, or if the fragments are severely displaced, the cast must be removed immediately The limb is then carefully (fig 2166 a) placed on a Braun splint and under local anesthesia a pin or wire is put through the tibial tubercle Then not more than a tenth of the body weight is used as traction weight, and correspondingly less in the presence of large wounds of muscles The positioning should be carried out as in figures 1604—1607

From 1916 to 1918 in our Special Army Hospital for Gunshot Fractures and Gunshot Wounds of the Joints at Bozen we treated all gunshot fractures of the femur with skeletal traction, although at that time, particularly in infected cases, many surgeons did not use the method, argued against it and, indeed, even forbad it

Exposure of Pus Foci If the wounds have been débrided with a scalpel at a forward dressing station or at a field or base hospital, if there is no prominent evidence of inflammation, and if little or no pus is discharged on pressure, the transport immobilization is left If no wound débridement with the knife has been carried out, it is best to correct the shortening by gentle continuous traction (Vol I/figs 247—249) and then, i e, after 1—2 hours, to enlarge the wounds under general anesthesia and to explore them digitally. From the ends of pus cavities, incisions 6—8 cm long are made through

[1] Franz Kriegschirurgie, Editions 1—4 Berlin, Springer 1944

which the digital exploration is continued On the lateral side of the thigh the incisions sometimes reach the trochanteric region, on the medial side they may reach the origin of the adductor muscles Bone splinters lying completely free are removed, as are of course any bullets, shrapnel fragments, etc Bone splinters which in any way cling to the soft tissues must, by all means, be left in place in an attempt thereby to avoid defect pseudarthrosis 6—8 cm - long rubber tubes are inserted in the incisions and stitched to the skin They must never be drawn transversely "through-and-through" the thigh, since they must be kept clear of the vessels Vol I/figs 244—246 show how erosion hemorrhage can be avoided When wound cavities are explored digitally, one always finds traversing cords They contain vessels and nerves and their severance would lead to severe hemorrhage This exploration operation should be performed in bed with the limb subjected to continuous traction If the traction weights are removed the fragments become re-displaced The positions of soft tissues and vessels then change (Vol I/figs 247—249) and immobilization is most severely disturbed Sometimes it is expedient to make one big incision along the whole lateral side of the femur and to close it later by secondary suture (see Vol I/pp 156, 185)

After wide exposure of the pus foci, fever usually subsides within the next few days But there are exceptions

In *gas phlegmon and in malignant epifascial edema,* multiple longitudinal incisions 5—6 cm long are made parallel to one another at intervals of 1—2 cm and carried proximally and distally a few centimeters into healthy tissue If all the edematous and purulent tissue has been widely exposed, this dangerous infection can usually be stopped Large doses of antibiotics should also be given

Genuine *gas-gangrene* is characterized by the sudden onset of severe pain and malaise, very rapid pulse rate, discoloration of the wounds and the issuance from them of a foul-smelling reddish secretion Pus does not form The swelling and discoloration increase quickly from hour to hour Before the antibiotic age I never saw a recovery follow either big incisions or amputation Gas gangrene serum was equally ineffective, and the patient usually died within the first two days Nowadays, under favorable conditions, gas-gangrene can be prevented and sometimes even cured by penicillin and/or other antibiotics When the wounds have been thoroughly excised with the knife on the first day, and when no vessels have been severed or have become thrombosed, gas-gangrene will not occur

Correction of eventual displacement is performed as in closed fractures of the femur In comminuted fractures this is very simple Antecurvature in the proximal third always disappears, as does varus, simply with correct positioning and appropriate traction The gallows or the thigh splint should not be moved beyond the lateral margin of the bed, as this would stretch the adductors too much and, inasmuch as proper traction always corrects varus deformity, is entirely unnecessary Excessive traction, however, causes valgus angulation (figs 1975—1977) It is not necessary in fresh fractures to drive a pin vertically into the proximal fragment for application of traction and to

allow leverage reduction In old fractures this is necessary (M. N/figs 761 until 766)

Further Treatment of Infected Gunshot Fractures of the Femur

Check Roentgenograms After 1—2 days, roentgenograms should be made in both planes to determine whether the traction is perhaps too strong or too weak It is very important to decrease the amount of traction weight at once if the fragments are distracted, in order to avoid the poor sequelae described in Vol I/pp 25—27 If there is shortening, the traction weight is increased Angulation is corrected, as gently as possible, in the same way as in closed fractures of the femur (figs 1991—2015) The use of a suspension sling (fig 2009) corrects "lateral" displacements not only in the sagittal plane but also in the frontal plane

Further check roentgenograms should be made every second week

Treatment of the Wounds Many authors attach great importance to the application of various ointments, to irrigating the wounds with various chemical solutions, to the injection of various chemical agents into the bloodstream, to the use of auto-vaccines and to irradiation with all sorts of lamps, with short waves and with X-rays And then in addition to all these things many demand early movement of the injured joints and massage I have seen military hospitals in which several hundred cases of gunshot fracture and of gunshot wounds of the joints were treated in such ways for months Everyone was hard at work The wound secretions were microscopically examined to discover the germs responsible for the infection and to fight them with specific chemicals and vaccines The blood corpuscles were counted The number of the erythrocytes was found to be diminished, that of the leukocytes to be increased The wounds were irrigated and dressed every day, the draining sinuses were spread and widened again and again to empty the pus The injured joints were moved to prevent their stiffening Little importance was attached to splints and immobilization To permit the patient to move the joints adjacent to the wound, very short splints were applied and these were removed for the exercises and the daily change of dressing Many patients had no immobilizing bandage at all Their bones were angulated For months patients ran high temperatures, and in spite of their youth they looked aged and miserable With their waxen complexion and shaggy or strangely thinned and woolly hair they presented the perfect picture of chronic sepsis Then at my suggestion a new medical officer was put in charge of those hospitals He had a fundamentally different attitude toward the whole treatment The patients whose fractures had not yet united were given plaster casts or were put in traction Where the roentgenogram showed sequestra, an incision was made widely exposing the fracture site, and necrotic bone fragments were thoroughly removed Irrigation of the wounds and all injections were stopped When I returned six weeks later, most of the patients looked well Their hair was smooth and shiny again They felt no more pain and they slept well Particularly interesting were those patients whose fractures had already firmly united but who had

still been plagued by draining sinuses Removal of the sequestra, discontinuance of the wound irrigation, and less frequent dressing of the wounds had sufficed to reduce the severe swelling which had persisted for months and to diminish or stop completely the suppuration Yet I should like to point out that the patients' diet — so important to the healing of wounds — had not been changed at all After the plaster and traction bandages had been applied during the first few days following the change in regimen, not only the patients but also the doctors and the nursing staff found some peace The demand for dressing material dropped to 5 per cent of what it had been before, and the demand for many and various chemicals and drugs ceased altogether

After extensive exposure of the pus foci, the essential and most important part of the treatment of any gunshot fracture of a bone and gunshot wound of a joint is complete and never-interrupted immobilization of the well-reduced fragments. *This diminishes the dangers to the patient's life and limb Good reduction of the fragments and their permanent immobilization in good position afford the best conditions for adequate drainage of pus and for the future usefulness of the limb As soon as immobilization is interrupted, the fragments will be displaced anew, fresh festering cavities will be formed with all their dangers to life and limb, and, if the surgeons actually succeed in saving both, the limb is likely to be bent, shortened, twisted and limited in its mobility*

Antibiotics are effective only against infection, never against angulation or limited mobility.

No medico-mechanical treatment will later be able to straighten out the bones healed in angulation and with shortening. *Therefore, throughout the whole period of treatment check roentgenograms must be made regularly to allow the surgeon to be sure that the fragments are in good alignment or, if they are not, to allow him to recognize that fact and so to be able to correct any displacement immediately*

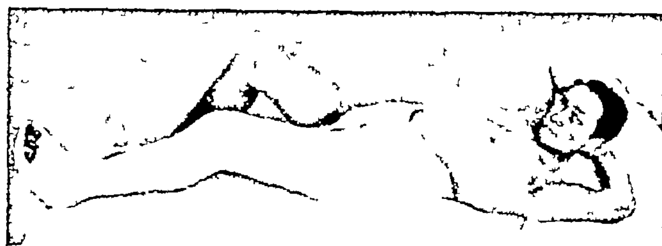
Thanks to complete and uninterrupted immobilization, not only will the bones heal but the soft-tissue wounds, provided they are not irritated chemically or mechanically and if they are dressed as seldom as possible, will also heal Frequently a dressing can be left for a week or, in some cases, even for several weeks To prevent decomposition of the pus in the dressing and the resultant foul smell, each layer of cellulose is thickly powdered with boric acid This also stops the growth of pyocyaneus Powdering the wounds with animal charcoal, castor sugar or other agents of similar purpose may also be helpful If the patient's skin shows a tendency to develop eczema it should be thickly covered with zinc paste, because the secretions of eczema would irritate the wound which would in turn discharge more secretions of its own

Exposure Treatment of Wounds Wounds in the distal half of the thigh can also be treated without any dressing at all The pus must, however, be drained in such a way that the bed-linen does not get soiled If the wound happens to be on the flexor side, *small* windows are cut into the cast and the surrounding area is protected by means of waterproof cloth or plastic and zinc paste Large windows in the cast should be avoided, since they

cause a "window edema" as depicted in figure 2510 and because recurvation of the fragments may then tend to occur

It is advisable to switch over from exposure treatment to closed wound treatment and vice versa from time to time and, if salves are used in the closed treatment, to change them after a while Large wound areas should be covered with split-thickness skin grafts or with pinch grafts as soon as the wounds are clean (Vol I/figs 157—158 c)

Avoidance and Treatment of Tubular Abscesses They will not develop if the wounds are carefully and thoroughly cleaned with the scalpel on the first day or if, on the day of admission to the special hospital, drainage



2166 d, photographed in Spain, 1937



2166 e, at Bozen on August 10, 1916



2166 f

FIG 2166 d—Closed transportation plaster cast for gunshot fracture of the femur Slight flexion of hip and knee Photo by Jimeno Vidal, Spain, 1937

FIG 2166 e, f—Italian P O W with infected gunshot fractures of the left femur and the left ankle Septic fever on admission Fenestrated and reinforced plaster hip spica brought temperature down to normal Patient recovered quickly Photo taken at Bozen on August 10, 1916 It was my first fenestrated and reinforced plaster hip spica It does not reach far enough cranially, and the sole part of the cast fails to extend to the tips of the toes

incisions are made in the manner described on page 1490 Once they have appeared, however, they must be explored digitally and all their nooks and crannies and extensions must be opened up Sometimes these abscesses extend as far proximally as the gluteal fold and the adductor tendons If neglected, they may break through into the lower leg or retro-peritoneally posterior to the inguinal ligament To avoid such development, some surgeons put the patient's extended limb in a horizontal position in the bed This position is not favorable to the correct alignment of the fragments, nor does it facilitate changing of the wound dressing There is no need for it after timely evacuation of the pus foci

Septic Secondary Hemorrhage This is one of the most dangerous sequelae of infected gunshot fractures of the femur I myself lost 7 out of 111 cases because of this complication Usually it occurs only in patients running very high fever, sometimes when they raise their intra-abdominal pressure during defecation, sometimes with a violent cough, occasionally for no



2166 g, January 19, 1940 2166 h, 1, May 3, 1917

FIG 2166 g—Osteomyelitis of the femoral shaft after femoral gunshot fracture The shaft is surrounded by new periosteal bone and forms really a huge sequestrum

FIG 2166 h, 1—Typical ring sequestrum from an infected femoral amputation stump It is apparent that only the peripheral part of the cortex is involved and not the area bordering the medullary space



September 26, 1917

FIG 2166 j—Sequestra following infected gunshot fractures of the lower leg Only superficial and delicate parts of the cortical bone are normally sloughed from the widely-exposed fragments

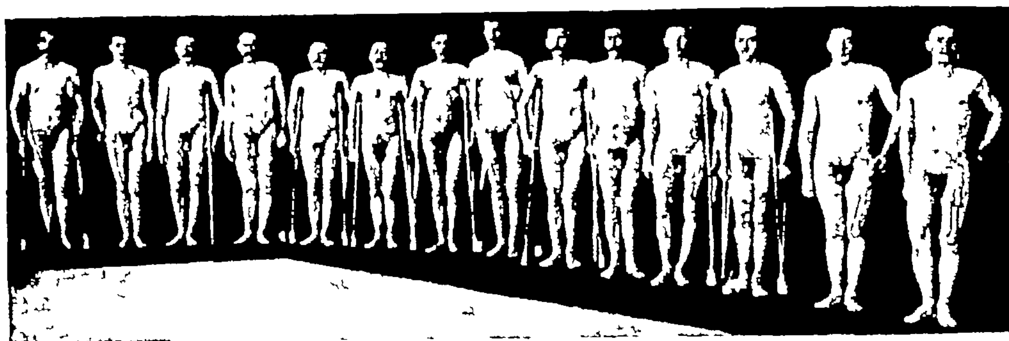
apparent reason at all and mostly at night The most dangerous period is that from the second to the fourth weeks The complication can be avoided if the pus foci are exposed in good time, i e before the thrombi in those areas are infected and softened by that pus, if no drains are passed right

through the whole limb, pressing against the vessels and eroding them, or if, in case of chronic insurmountable sepsis, one amputates *in time*

If one fears that septic secondary bleeding might occur, one prepares a tourniquet proximal to the "danger zone" so that if necessary it can be tightened at once Then, in case of bleeding, blood, plasma or some substitute liquid, e g, Tutofusin, is given One should never be content with a mere tamponade If no tourniquet was previously applied and if bleeding stops before an Esmarch tourniquet is applied, which frequently happens, one should not be content with that, either, because the bleeding episode is likely to repeat itself after hours or days and then is nearly always fatal As soon as the patient, usually wasted, has recovered following administration of blood transfusions and heart stimulants, the wound must be exposed under general anesthesia and with use of a tourniquet, the offending blood vessel must be found and carefully ligated With wounds in the proximal third of the thigh, no tourniquet can be applied in the form of a circular ligation In those cases a pin is driven into the greater trochanter or else a small cut is made and a forceps is passed through beneath a bit of fascia Then the tourniquet is passed proximal to the pin or forceps and pressure is exerted just distal to the inguinal ligament If the bleeding is from the main artery the limb must be amputated immediately, as otherwise it will surely become necrotic If after mere ligature the high fever persists, the limb must be amputated later Many such patients do not survive this operation Such cases of sepsis have fortunately become rare in our antibiotic age

Amputation If the patient is feverish for weeks and his condition deteriorates, the limb should be amputated in good time Amputation must also be done in case of bleeding from the main artery, as noted above The method of amputation is described on page 1484

Osteomyelitis A great deal has been written about osteomyelitis following gunshot fractures In actual fact, in my experience it has occurred very seldom Osteomyelitis is an infectious disease of adolescence which appears suddenly and without any apparent external cause, much like angina or appendicitis At first the bone marrow is affected Then extensive abscesses form round the bone, raising the periosteum The latter forms new bone in the course of a few months, while small or large sections of the bone itself become necrotic and are finally discarded by the parent bone In studying many thousands of roentgenograms and in being present at the post-mortem examinations of some hundred cases of gunshot fracture, the bones of which specimens I invariably had sawed through lengthwise, I have very rarely come across this picture and only once in a pronounced form That one case was that of a gunshot fracture of the femur in a Polish prisoner of war (fig 2166 g) As a rule, the inflammation of the bone marrow at the fracture ends is only 0 5—1 cm deep Only when there are longitudinal fissures for the infection to follow does it go farther It is, therefore, usually the so-called "ring sequestra" which are discarded from the fracture ends, so that little actual length is lost from fracture ends that are not comminuted (figs 2166 h, i)



May 22, 1918

FIG 2166 k —1 to 6, closed fractures of the femur, 7 to 14, gunshot fractures of the femur All are shown 2–6 weeks after removal of traction Roentgen findings re the injury are sketched on the sound limb This is not a group of highly selected cases, but all cases which had healed in four weeks were included

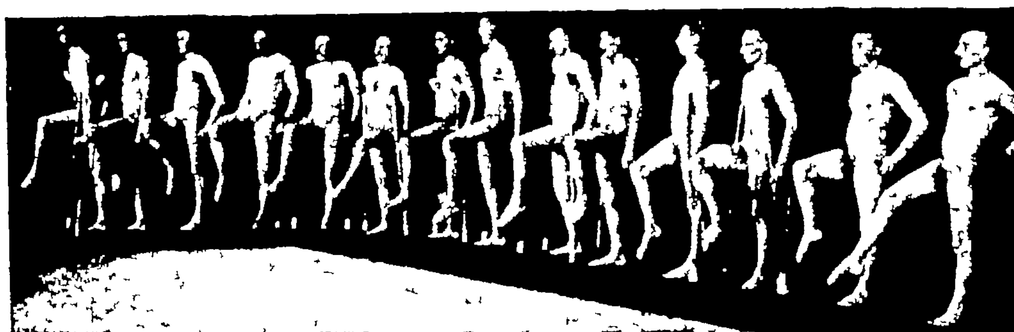


FIG 2166 m —With the exception of cases 6 and 14, all patients can bend the knee on the involved side more than 90°



FIG 2166 n —Good muscle power in all Full active extension of the knee not yet recovered except in case 13 No case of drop-foot

Treatment of Infected Gunshot fractures of the Femur by Thoracopelvic Hip Spica

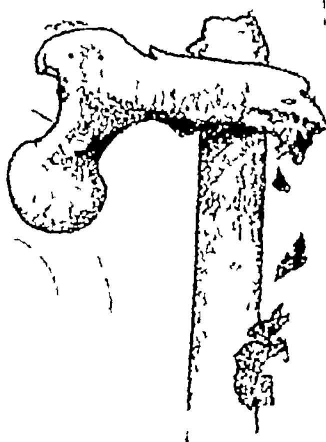
During the first World War I treated all gunshot fractures of the femur by continuous traction I have, however, the impression that a plaster thoracopelvic hip spica should be applied reaching from the toes up to the axillae in severely infected cases Also, the thigh of the sound side should in some cases be included to secure complete and uninterrupted immobilization

Immobilization is disturbed to some extent in traction treatment when the wounds are dressed and when the patient moves his bowels Such a plaster cast must be adequately fenestrated (fig 2166 f) Avoidance of "window edema" is discussed on page 1156 When the fever subsides, traction must usually be applied again for a while If all pus foci have been exposed it is sometimes expedient to keep the plaster cast closed

If the fragments have failed to unite even after a long while, a walking plaster cast may be applied

Exercises. In clean as well as in infected cases, toes and ankle joint must be *actively moved through their full range from the first day on* In the case



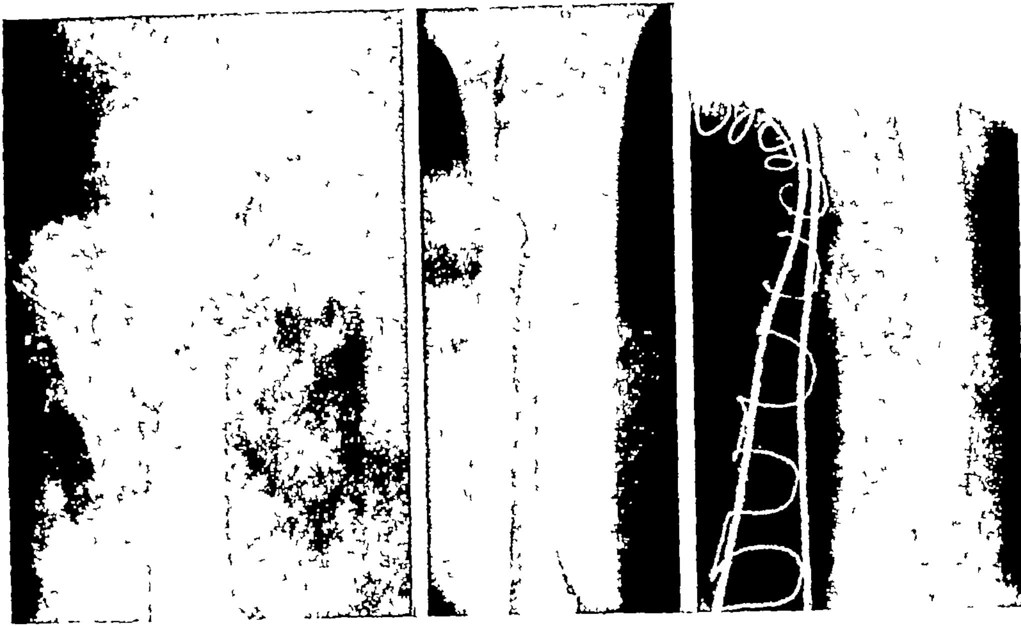


2166 o 2166 p

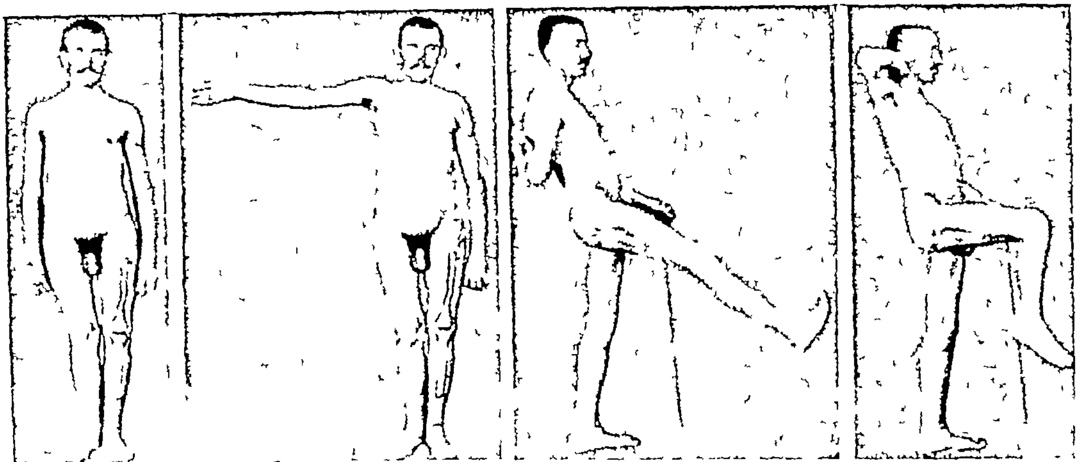
Fig 2166 o—End-result of a gunshot fracture of the femur after various changes in the treatment (change of methods, change of hospitals, change of surgeons), 13 months after wounding Shortening of 22 cm, varus of 90°, stiff knee and drop-foot Seen by Dr Fiselsberg in 1917

Fig 2166 p –Sketch of roentgenogram re figure 2166 o

of a paralysis, slings for each toe are used so that the patient can manually pull the toes dorsally If there is still a tendency towards flexion contracture, a plaster-of-Paris sole reaching to the tips of the toes is applied A piece of foam rubber or cellulose wadding is put then between the plaster and the toes. By this means the toes are elastically held in slight dorsiflexion and can actively be flexed against the resistance In aseptic cases the hip joint also is exercised by the patient s sitting-up, in infected cases one must be careful In aseptic cases the muscles of the thigh are actively contracted from the third week on, in infected cases this is started only when the fever has subsided As soon as the temperature has fallen below 37.5° C, the sound limb is exercised on the 'mountain-climber" apparatus (Vol. I, figs 21, 22)



2166 q 2166 r 2166 s
May, 1918



2166 t, August 4, 1918

Figures 2166 q—s refer to the photographs shown in figure 2166 t

FIG 2166 q —Infected "gunshot' fracture of the proximal third of the femur actually caused by a grenade Essentially the same fracture site as in figure 2166 p Rubber drain with safety pin shown in the wound

FIG 2166 r —*Open* flexion fracture of the distal third of the tibia and closed flexion fracture of the proximal third of the fibula

FIG 2166 s – Closed flexion fracture of the humerus

FIG 2166 t –Photographs re figures 1607 and 2166 q—r, three months later Bony union across all four fractures resulting from uniform, well-planned treatment without change of hospital or surgeon Good position, no shortening The wounds healed with smooth scars, sinuses did not develop No considerable atrophy of the muscles Patient can already walk without a cane Roentgen image of the injury is sketched on the sound limb

Arm exercises, which at the same time are breathing exercises, are also carried out This is described in detail on pages 1204—1208

Avoidance of Shortening If no bone splinters were earlier removed, shortening of more than 2 cm can always be prevented by well-planned and consistent treatment in continuous traction

Avoidance of Angulation With regular check roentgenograms, angulation can always be detected in time and gently corrected by appropriate positioning Angulation of more than 10° must be eliminated to avoid later arthrotic changes in hip and knee Such changes sometimes supervene as late as after 20 years (see page 1385)

Avoidance of Loose Knee Joints Loose knee joints may develop when continuous strong traction has been effected distal to the knee joint for more than four weeks In cases of great shortening, loose joints occur even without the use of traction They can be avoided easily and completely *if continuous* traction is applied *proximal* to the knee joint from the fourth week on and if marked shortening is avoided

Avoidance of Drop-foot Drop-foot is often seen after fractures of the femur. It never develops if forefoot traction as shown in figures 1604 until 1607 is used during treatment by traction or if the sole part of the plaster cast extends as far as the tips of the toes

Avoidance of Flexion Contracture of the Toes Apart from paralysis, the cause of this is failure actively to excercise the toes from the beginning Flexion contracture of the toes is a severe handicap in walking, and it usually can be easily avoided if the toes are *actively exercised from the beginning* In the case of paralysis, the toes should be manually moved by the patient by means of individual slings for the toes, or else rubber or cellulose should be applied between the toes and the plaster sole (see page 1498)

Period of Immobilization. Aseptic comminuted fractures sometimes unite within 5—10 weeks and weight bearing can then be begun This takes much longer in infected fractures Jimeno Vidal has calculated that an average of 17 to 20 weeks are required In rare cases, immobilization must be continued for a whole year and more If the traction or plaster cast is removed before the fracture has solidly united, reangulation will occur or the bone may fracture again

Further treatment is carried out as in gunshot fractures of the hip (see page 1158)

Forceful massage and energetic passive movements must be avoided Even after months these measures may cause an infection to flare up and spread, and they may irritate the neighboring joints

Exercises must not cause pain (see Vol I/45)

Replacing Lost Skin When the wounds have become clean they can be covered with split-thickness skin grafts or with pinch grafts as described in Vol I/p 156 (Vol. I/figs 157—158 c and 1501—1505)

Removal of Sequestra If draining sinuses are present and if sequestra or shell splinters etc are seen on the roentgenograms, those latter should be removed in a bloodless field and under general or spinal anaesthesia. The sinuses are filled with a radiopaque medium before operation in order to

help the surgeon determine their location and extensions In fractures of the proximal third, a pin or a forceps is used to hold the tourniquet (see page 1484) The sinuses must be exposed by long incisions and traced into their last ramifications The edges of the bones should then be smoothed with a chisel so that the soft tissue can easily fill the cavities After the cavities have been cleaned they are filled with Vaseline or Unguentolan and the skin is closed with a few widely spaced sutures The dressing should be changed as seldom as possible it can sometimes be left for some weeks Swabbing or irrigating these bony cavities delays or prevents healing, as hard tylomatous scars develop whose walls cannot approach each other If the position of the fragments is good, the sinuses as a rule close quickly after removal of the sequestra In gross displacement there are usually big, irregular cavities which often fail to close Sequestra should not be removed earlier than 4—6 months after the original wounding

Non-Union Following Gunshot Fracture of the Femur

The pieces of bone shot out of the femur are never so big that the fragments can no longer unite The main cause of non-union used to be primary or secondary extensive removal of splintered bone Nowhere else is this as disastrous as it is in the femur It must therefore be stressed again and again that *the bone splinters never cause sepsis* but that sepsis is rather the consequence of insufficient exposure of pus foci and insufficient immobilization If all bone splinters are removed, or even the bone ends sawed off, large defects will occur in the bone so that the limb finally hangs only in a soft-tissue "sleeve" and its function cannot be restored either operatively or with braces During World War I the French removed all bone splinters in gunshot fractures and gunshot wounds of the joints According to Franz (see page 1490, footnote), the result was that amongst the 37,746 gunshot fractures of the femur treated in French base hospitals, 10,908 (28 8%) had to be amputated later on because the limb had become completely useless

At present, continuous excessive traction is the most frequent cause of non-union Excessive traction leads to gaping of the fragments and delayed callus formation not only in transverse fractures but also in oblique and comminuted fractures (Medullary Nailing, figs 748—770)

The treatment of non-union is described on pages 1467—1472

Old Gunshot Fracture of the Femur

If the wounded are admitted for treatment weeks or months after wounding with shortening and angulation of the femur, callus is so soft that the shortening can be corrected by continuous traction

If the fragments have united by soft callus, angulation can be corrected over a wooden wedge or with Phelps-Gocht's apparatus (Vol I/fig 138), provided suppuration is not severe

If the fragments have united by bony union, shortening and angulation can be corrected only by open osteotomy Formerly I operated not earlier than six months after closure of the sinuses In favorable cases I have lately

osteotomized at the time of sequestrectomy and have then applied pin or wire traction In general it is better to do a V-shaped osteotomy in the sound part of the femur six months after the sinuses have closed

Extension Contracture of the Knee Joint Following Gunshot Fracture of the Femur

This occurs frequently and, under favorable conditions, it can be treated as described on pages 1473—1476

Drop-Foot Position and Flexion Contracture of the Toes Following Gunshot Fracture of the Femur

The *drop-foot* is treated by closed achillotenotomy

In *flexion contracture of the big toe*, the base of the proximal phalanx is excised

Flexion contracture of the second to fourth toes is treated by excision of the distal ends of the proximal phalanges The trochlea is exposed and excised by an incision through the skin and extensor tendon Through-and-through stitches are then taken through skin and extensor tendon

Results in Gunshot Fractures of the Femur

Mortality There were 22 (3 6%) deaths among Jimeno Vidal's 600 cases The mortality was 6 52% among Wustmann's 468 cases There were 28 (8 9%) deaths among Argulles' 316 cases, and 13 (11 7%) deaths among my 111 cases In the Crimean War the mortality was 86.6%, in the German front hospitals in World War I it was 42 6%, according to Franz

Amputations Jimeno Vidal had no survivors among his amputated cases Five per cent of Arguelles cases were amputated, as were 2 7 per cent of mine But 28.9 per cent of the cases reported by the French were amputated

A survey of deaths and amputations is given in Vol I/p 280

Functional Results Jimeno Vidal reported that the average shortening was 0 4 cm and that 83 per cent of his cases healed without angulation Of his cases 47 6 per cent had knee motion through more than 110°. Ankle joints and toes were always freely mobile There were no cases of drop-foot or pressure ulcer about the heel. My own results are given in Vol I/p 280

Questions We Should Ask Ourselves to Avoid Failures When Treating Gunshot Fractures in Military Hospitals

When treatment analogous to that for infected gunshot wounds of the hip joint (see page 1159) has been given, the following additional questions should be considered·

1 Have I, in the wound débridement, left in place and *not removed* bone splinters, in order to avoid defect pseudarthrosis?
2 Have I avoided closing the wound by suture, as this might cause severe suppurative infection or gas-gangrene?

INDEX